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THE CASTING OF BRONZE STATUES *

THE DELICATE AND INTRICATE WORK THAT IS PRODUCED IN SAND MOLDS.

By Snowden B. Redfield.

What is probably the very highest branch of the molders' art is in the casting of bronze figures and statues. From its very nature it is essential that the bronze casting shall exactly reproduce every contour and every mark that is put upon the plaster figure sent by the artist to the foundry to be cast in bronze. What makes this fine work all the more difficult is the fact that these statues, unlike the patterns for machinery castings, are not parted in the usual sense of the word, and furthermore they are nearly always exceedingly complicated in contour, having many parts which are undercut in order to represent the various portions of the human body, and also the natural folds of the clothing and draperies.

NO CORE BOXES.

The ordinary machinery molder would expect the pattern for this work to be provided with almost an infinite number of core boxes for forming the cores for these undercut parts, and in his imagination the pattern of the main figure would be literally bristling with core prints in which to set these cores. As a matter of fact, an ordinary statue has no core boxes at all, and the number of core prints on the pattern is practically *nil*.

Many of the most celebrated statues lately designed have been cast in the works of the Gorham Manufacturing Company at Providence, R. I. Fig. 2 is a photograph of one of their products, the Sheridan statue recently erected in Washington, and the horse, which is also shown in Fig. 1 as suspended from the shop crane, is said to be the only equestrian figure of any size which has been cast in one piece in this country. It is also said that this casting is the largest single piece bronze casting ever poured in this country.

From these remarks it will be surmised that statues are not all made in one piece. This is true, for many of the projecting parts, such as arms and legs, are cast separate and afterward fastened onto the main casting, this fastening being so perfectly done that it is practically impossible to detect the joint. Horses are usually cast in eight pieces, so that the one shown in Fig. 1 is really a remarkable piece of work. The method of making the joints will be described later on.

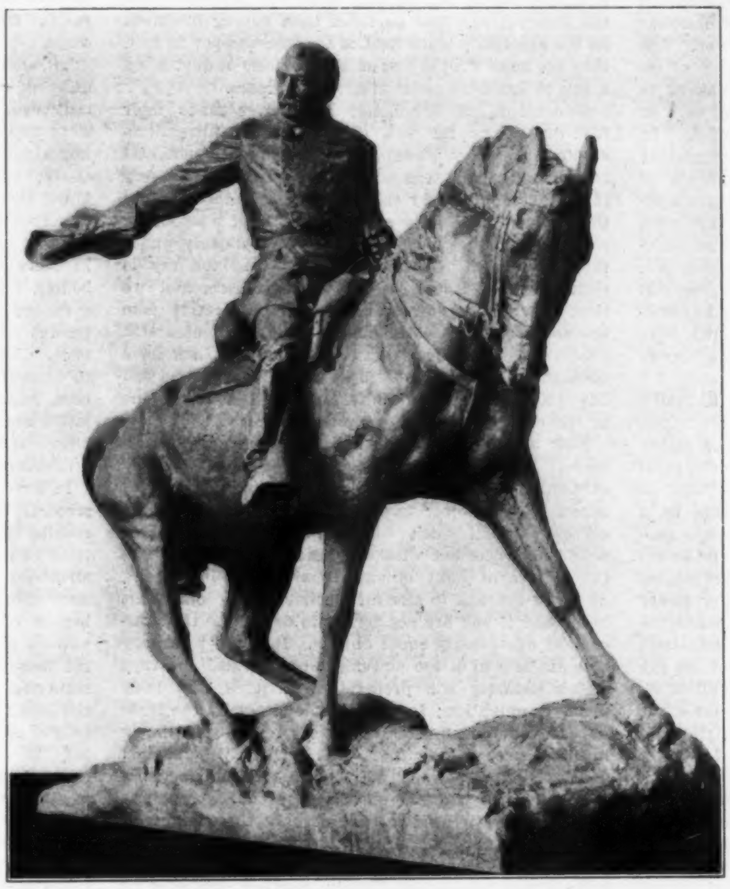


FIG. 2.—THE COMPLETE SHERIDAN STATUE, WASHINGTON, D. C.

RAMMING THE MOLD.

First as to the casting. Let us imagine a figure with flowing drapery and with the head and arms and feet all in one piece. The molder first selects that plane in which it will be easiest to split his mold into the cope and drag, although as already said the pattern itself is not split, but is a plaster model, an exact duplicate of the clay figure made by the artist himself. This figure is then buried in sand in the cope up to the level convenient for parting the mold, it, usually, being laid down on its side. The sand is smoothed off around the figure and soapstone applied to the surface to make a parting.

After this the drag is put on and the molder using a special grade of French molding sand, which is very sticky, rams a small quantity of this sand into every one of the undercut parts on the upper side of the plaster figure which will not draw out of the mold when completed, confining himself to but a small portion at a time. He packs this sand in tightly with a small hammer, and after trimming the edges, he carefully lifts out this small core, so made, by means of a pointed wire. Next he dusts it all over with soapstone to give it a parting surface, and then lays it back in place. He now proceeds to the next undercut section, which may be a continuation of what he has already been working upon and makes another little core, which fits the undercut part of the plaster figure and also fits right up to the small core already made. This little piece of new core is now lifted out, dusted over with soapstone and put back as before. This is repeated until every undercut portion of the figure which is exposed above the main sand has been provided with a little core, and each one of these cores can be lifted out separately, while all their combined outside surfaces form such a shape that it will easily draw out from any mold which is made on the upper half of the figure.

When all the little cores have been made, and it will be noticed that no core box other than the portions of the main pattern itself has been used, the whole figure is practically covered over with these little cores, and next the whole surface is soap-

(*Continued on page 168.*)

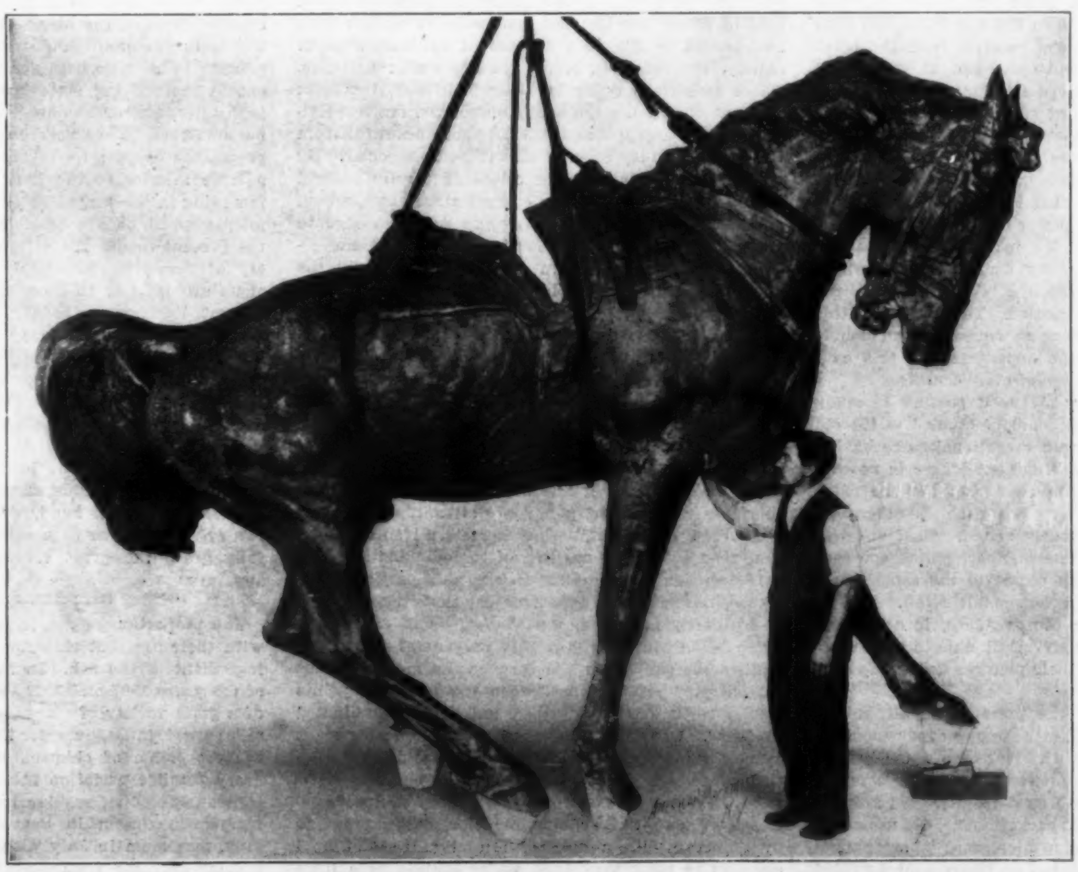


FIG. 1.—PART OF SHERIDAN STATUE, WASHINGTON, D. C., SAID TO BE THE ONLY BRONZE HORSE OF LARGE SIZE EVER CAST IN A SINGLE PIECE IN THIS COUNTRY.

THE CASTING OF BRONZE STATUES.

* Reprinted by permission from American Machinist.

THE STUDY OF THE INVISIBLY SMALL.*

ULTRAMICROSCOPES AND ULTRAMICROSCOPICAL OBJECTS.

BY A. COTTON AND H. MOUTON.

Of all our senses, seeing gives us the most extensive knowledge, and we have the greatest confidence in what we have learned by the eye; consequently, when we try to increase our perceptions by the aid of instruments, we pay especial attention to those that enable us to *see* new objects. Hence it is that the telescope on the one hand, and the microscope on the other are, perhaps, the instruments most familiar to those who do not frequent the laboratory. The microscope in particular owes a large number of its improvements to the constant desire of makers to satisfy their public, which is made up not only of regular scientists but also of amateur scientists. In some cases the latter have been found more exacting than the former. Thus, these amateur students of nature wished to study the marks and ornaments on the shells of the diatomaceæ. Scientifically, this work was of no great importance, either practical or philosophical, and its only reward was the vanquishing of a difficulty. But from a mechanical point of view, it was of real use, for it called for still greater improvements in the microscope, which improvements have been utilized by the regular scientists in more than one field.

But, notwithstanding all the care taken by the manufacturers of microscopes, the result obtained is limited. It is true that greater magnifying power might be attained, but this is without real interest, for the ideal microscope would be the one in which each point in the object under view would be imaged forth by a point of inappreciable dimensions. But what really happens is this: Even in the best instruments, the image of a point is always a small spot whose dimensions increase with the increase of the magnifying power of the instrument, so that when two points are too near one another in the object under examination, their images lap over one another a little and the eye is no longer able to separate them. The smallest resolvable distance, though this depends somewhat on the nature of the object that is under examination, is never less than a quarter of a thousandth of a millimeter, even when the very best instruments are used. The explanation of this limitation of the powers of the microscope has been found in the nature of light itself. Considering light to be a result of vibratory motion and taking into account the phenomenon of diffraction which is peculiar to the microscope as to all optical instruments, we can calculate the diameter of the spot forming the image of a point and show that this diameter will be smaller if, in the first place, the cone of rays which the instrument receives from the point under consideration is more open, and, in the second place, if this point is placed in a medium of higher index and sends out rays of shorter wave-length, viz., nearer the violet in the spectrum, if we consider only visible rays. But with the instruments now in use, permitting homogeneous immersion and great numerical aperture, we may say that the limit assigned theoretically to the resolving power of the microscope has been practically reached. We may hope, however, to extend it a little further by employing ultra-violet light, to which, though the eye is not sensitive, the photographic plate is sensitive. Yet, even by this method, we can hardly hope to do more than double the resolving power of the apparatus and this only after surmounting great technical difficulties.

But the ultramicroscope makes it possible to study much smaller objects than could be studied in the old way, these objects in certain exceptional cases having the millionth part of a millimeter. There is no contradiction between this statement and the one made a few paragraphs above, for this problem differs entirely from the one previously stated. That one was the distinguishing from one another, points set very closely together, or, which comes to the same thing, determining the form of a very small detail. But we refer now to ascertaining the existence, in a homogeneous medium, of extremely small objects which are far enough apart so that their pictures do not lap over one another.

It may be asked how the presence of ultramicroscopic objects is revealed in a homogeneous medium. The answer is by using with great care a method employed by amateurs of the microscope, often in a rather imperfect manner, but with good results. We refer to the lighting up of a dark background. Consequently, an ultramicroscope is not a microscope whose optical parts have been improved, but an instrument provided with a special mode of lighting. The rules to be observed in this lighting have been laid down by Siedentopf and Zsigmondy, who were the first to make known this method to the scientific world. Light must be thrown as intensely as possible on the little objects which are to be studied. They then appear luminous and can therefore be observed if care has been taken to place the apparatus in such a position that no luminous ray of the lighting shaft can penetrate into the object-glass. The particles then appear luminous on the absolutely black field of the microscope; in fact, they are made visible just as are particles of dust when a ray of sunshine penetrates a dark room.

Siedentopf and Zsigmondy themselves made their first apparatus for the observation of ultramicroscopic objects, by whose use a convergent horizontal ray of light brightens under the microscope a very thin layer of the body that is being examined. Since then a somewhat different plan has been adopted by us. We introduce a ray of light very obliquely under the body which is being examined, and the ray is then wholly reflected on the upper surface, and we thus prevent any direct rays from penetrating into the apparatus. Recently Siedentopf has invented still another kind of apparatus and other scientists have done the same. Each of these inventions has certain advantages and certain faults, and it is best to use one or the other according to circumstances.

Now a word about the lighting of an ultramicroscope. You get the brightest and cheapest light by utilizing ordinary sunlight. This gives a wonderful aspect to the object under view and enables the observer to distinguish very minute particles which would not come out with any other sort of light. But this source of light is unfortunately too inconstant, and you are apt to use an electric arc, if one is at hand, and if you are not trying to determine the presence of exceedingly small objects. It is not necessary to make use of a too powerful arc provided the rays strike squarely the preparation, that is, the body under examination; for the light emitted by the little objects which you perceive depends on the brilliancy of the source of the light, this brilliancy being the same for all arcs, and not on the total intensity of this light. In the vast majority of our experiments we have always used an arc of only three amperes, which can be bought at a reasonable price.

When you examine a transparent body containing little ultramicroscopical objects, you are reminded of the starry heavens when seen through a telescope. If you examine certain glasses colored by traces of metal, gold or silver, for instance, you perceive on the dark background of the field a mass of brilliant starlike objects, the reflection of the small metallic particles. These reflections differ in their brilliancy, the most brilliant ones being the reflections of the larger particles. Their appearance is all the more beautiful from the fact that they are not all of the same color. By examining in this way the colors of certain natural crystals—particularly those of crystallized salt, which are sometimes pink or white—one has been able to prove that this coloration is due to small ultramicroscopical crystals lodged in the finest fissures of the crystal and which we have reason to believe are formed by metallic sodium. This is rather a surprising fact if we remember that this substance is so easily oxidized that it is found nowhere else in a metallic state and that its preparation and conservation have long been considered by chemists as a very difficult problem.

If instead of a solid body, we examine a liquid holding little ultramicroscopical bodies in suspension, the same phenomenon is still more striking. But in this case the brilliant points are all animated by the "Brownian movement," which affects all small particles, even when they are but microscopic and are held in suspension in a liquid. But in this particular instance, this constant agitation sometimes becomes extraordinarily animated, the whole field of the microscope being marked by a sort of general swarming, often accompanied, in the case of the most brilliant particles, by scintillations, when the luminous points change color, are extinguished and then reilluminated by turns. One may enjoy this really admirable sight by employing for the experiment a very diluted solution of colloidal silver sold under the name of argyrol. Or one may examine one of those pretty "solutions" of gold, red or blue in color, easily prepared by reducing with a drop of formol a trace of gold chloride in some very pure water containing a little sodium carbonate. Under the most favorable conditions of light—sunshine at noon in July—and observation, you can discover in such liquids metallic particles whose average diameters have been estimated to have a minimum size of one-sixth millionth of a millimeter! Under less advantageous conditions, and especially when the little bodies which are being observed have not the optical qualities peculiar to metals you cannot of course expect to see anything except where the particles are considerably larger than this and yet far smaller than those seen in the ordinary microscope.

Ultramicroscopes have so far been used in very different sorts of research work, but the most important results have been obtained where colloidal liquids were experimented with. These liquids play a very important part in chemistry and in biology, especially; and thanks to the ultramicroscope, we now know for certain that colloidal bodies are not really dissolved in their "solutions," but remain there in a state of stable suspension. It has not been possible in every case to observe the little particles of these bodies, but we have good ground for believing that even the colloids which it has not been possible to resolve have a discontinuous structure like the other ones. This special state of the colloidal group helps to explain their particular properties, which have long been under observation, as, for instance, their coagulation and their electric transformation, this last phenomenon being especially observable through the ultramicroscope.

In a recent work—"Ultramicroscopes and Ultramicroscopical Bodies," Paris: Masson—we have given the results of our experiments in this field and have also tried to show how one can get at the composition and structure of colloids by combining our conclusions with those obtained by other students in this same branch of scientific work. Among the recent contributions to this problem, we have found especially useful those of Malfitano and J. Duclaux, who, by separating in certain cases ultramicroscopical bodies from the medium in which they are bathed, have been able to give us some idea of their composition. We are now led to consider these particles to be "granules" charged with electricity and englobed in a zone of matter carrying charges which are equal, but of differing sign, the whole forming an electrically neutral micella.

Not a few biologists have employed the ultramicroscope for the study of living things. By this means they have been able in some cases to follow the movements which take place in the interior of vegetable cellules through the displacement of the little bodies which they contain and which appear as luminous points. It has also been possible to make more apparent in their living state certain micro-organisms existing in water or humors. With this apparatus it is possible even to see very easily a microbe, in pleuropneumonia of oxen, for instance, whose dimensions are a little inferior to the limit of vision. The difficulties lying in the way of determining the form of ultramicroscopical objects have made it impossible up to the present to use the ultramicroscope in the discovery of numerous pathogenic microbes whose dimensions are inferior to those which can be seen under present lighting methods. It is much to be hoped that in some way we may be able to determine the specific optical character of these various small beings, some of which are the causes of terrible diseases.

We have just seen that the greatest service which, up to the present, has been rendered to biology by the ultramicroscope is in the field of colloidal liquids. If, on the one hand, we bear in mind how imperfect the studies in this department of science still are, and if, on the other hand, we remember that all living matter seems to be in a colloidal state, then we will fully grasp the great value to biology of this new apparatus.

* The Independent.

The proportion of ash in leaves increases regularly with their age, but this rule does not apply to every ingredient of the ash. In May, July, and September of the years 1907 and 1908 Vandevelde collected leaves of a great variety of plants in three localities, several miles apart, in Belgium, for the purpose of determining the proportion of chlorine in the leaves. He found every possible variation in the course of the chlorine content, including regular increase from May to September, maximum in September with minimum in July, maximum in July with minimum in September, regular decrease from May to September, and maximum in May with minimum in July. In many plants the chlorine content fluctuated irregularly. The cause of these variations is entirely unknown.

COLD IN MODERN LIFE.

THE IMPORTANCE OF REFRIGERATION.

BY CHARLES ENGEL.

Until nearly the end of the nineteenth century ice was used in Europe almost exclusively for cooling beverages and making ice cream. To-day, immediately after the meeting of the first International Congress of Cold, in which delegates from forty-two countries assembled in Paris, ice and other means of producing cold appear to be used for a great many purposes and to play an important economic and social rôle. The industrial use of cold was first made possible by two French engineers, F. Carré and Charles Tellier, who constructed the first machines by which cold could be cheaply and practically produced. In the years 1857 to 1863 Carré, with his ammonia machine, made extensive experiments which were finally crowned with success. In 1869 Tellier exhibited in Marseilles the first refrigerating machine in which ether was employed. Between 1868 and 1875 Tellier demonstrated the possibility of keeping meat for a long time in cold storage. The experiments were continued on the ship "Frigorifique," which in 1876 and 1877 made a voyage from Havre to Buenos Aires and back, carrying a cargo of meat, which was kept at the freezing point and remained in a perfectly fresh condition. Tellier proposed building a great fleet for the transportation of American meat to Rouen, where large cold storage rooms should be built. Financial difficulties prevented the accomplishment of Tellier's plan, but the Americans made use of the invention of the French engineers. Argentina, where before the voyage of the "Frigorifique" cattle and sheep were slaughtered for their hides and wool, and their flesh was thrown away, exported to England 400 slaughtered cattle in 1880 and 211,000 tons of fresh meat in 1907, in which year England also received 116,000 tons of fresh meat from Australia and 125,000 tons from the United States. Tellier's most ambitious hopes and expectations were thus exceeded.

The diet of the English people, rural and urban, rich and poor, has undergone a great change in consequence of the practical application of cold. Frozen meat of good quality can now be bought in London at wholesale for 7 cents a pound. In London, where refrigerated products from the whole world come together, it is possible to construct an elaborate bill of fare of fresh foods brought from many lands, thousands of miles away. The menu, for example, might contain eggs from Australia, salmon from Canada, crabs from Morocco, beef from Argentina, mutton from Australia, hares and poultry from Russia, unsalted butter from Australia, milk and cheese from Buenos Aires. The dessert might include bananas from Jamaica or Costa Rica, apples and strawberries from California, pears, peaches, and apricots from the Cape of Good Hope. This list might be greatly extended, so numerous are the good things that we can now enjoy at home, thousands of miles from the place of origin, thanks to artificial refrigeration.

Although the preservation of fresh fish is not yet as highly perfected as could be desired, an extensive commerce in frozen fish has developed, which has produced some peculiar results. The city of Basle in Switzerland, the focal point of railways from the Atlantic Ocean, the English Channel, the North Sea, the Baltic and the Adriatic, has become one of the most important fish markets in Europe.

The employment of cold in transportation and preservation of fresh fruits of every kind is daily making new advances. If suitable sorts are selected the flavor and aroma are preserved unimpaired. Apples may thus be kept two years, pears four or five months, plums two or three months. Oranges, lemons, grapes, tomatoes, cherries, even strawberries and raspberries can be kept for long periods in cold storage if carefully packed. Long trains of refrigerator cars filled with California fruit traverse the American continent in a week, supplying Chicago, New York, and other large cities. In order to keep fruit in good condition all the rules gathered from experience must be strictly followed, and the temperature and humidity most suitable for the particular kind of fruit must be maintained.

In hot countries, and even in Europe in summer, artificially-cooled air would be very welcome. We use heat to protect us from the cold of winter. Why should we not use artificial refrigeration to protect us from the heat of summer? Our modern dwellings, which are such perfect shelters in winter, should gradually be provided with appliances for the purpose of furnishing cool air in summer. This result may be accomplished by several methods. One process consists in causing rapid evaporation from moist surfaces by means of a strong current of dry air, thus utilizing the great absorption of heat which occurs when water passes from the liquid to the gaseous state. A pound of water absorbs, in evaporating, a quantity of heat which would raise the temperature of 1,080 pounds of water one degree F. or would melt seven pounds of ice. By the use of powerful blowers it is thus possible to lower the temperature of large rooms by eight or ten deg. F. This method of refrigeration is already used in some large factories in Italy and in the United States. If only one room is to be cooled, it is sufficient to produce a current of air cooled by natural or artificial ice. In a theater in Cologne, the temperature is kept below 70 deg. F. on the hottest days in summer by this method, which is also used in several large restaurants in Berlin and London. In several American cities artificial cold is distributed to houses from a central station, as steam is distributed.

By another application of artificial refrigeration flowers can be had at all seasons. By means of cold the vital activities of the plant can be checked for an almost indefinite period, and the natural winter sleep of plants can thus be prolonged at the gardener's pleasure. The florist can confidently undertake to deliver spring flowers in June, July, or August. This new method is already largely employed in Germany, England, Holland, and Denmark. The largest cold-houses for plants yet constructed are those of the Rochford Company in England.

This method is applied to a great many different plants, but especially to those of the rose and lily family. The plants or bulbs are taken up in February or March and kept until the following November or December in cold-houses at approximately the temperature of freezing. They are revived by being removed to hot-houses, where they grow with remarkable rapidity, as if to make up for lost time, and soon become covered with beautiful flowers. The lily of the valley blooms three weeks after being removed to the hot-house.

Very interesting results in floriculture are obtained by means of cold. Prof. Vercier of Dijon has shown that the development of buds, even when partly opened, can be arrested for a considerable period, and that cut flowers, including roses, lilies, and hyacinths, can be kept fresh in cold storage several weeks without losing their fragrance. When the plants and flowers which have been treated in this way are brought into the open air they behave precisely as if they had developed naturally.

For a long time artificial cold has been employed to give skaters an opportunity of practising their favorite sport in summer. Artificial ice rinks are to be found in many large cities. The finest perhaps is the ice palace in Berlin.

Artificial cold is used in many other ways in everyday life. Furs are protected from moths by being kept in cold storage at a temperature of about 39 deg. F., at which the eggs of the moth cannot hatch. Dealers in furs and woollen goods protect their wares against insects by keeping them exposed to a current of cold, dry air.

Artificial refrigeration is currently used in numerous industries, including the crystallization of sugar and salt, clarification of wine, manufacture of sparkling wine, of chemical and pharmaceutical products, glue, gelatine, photographic plates, India rubber, dyestuffs, explosives, beer, cheese, butter, candles, soap, perfumes, etc., and in laboratories, observatories, and elsewhere. Artificial cold is of inestimable service for the transport and preservation of fresh foods of all kinds. The engineer and promoter finds in artificial cold a valuable means of boring shafts in soft, wet ground. By means of refrigerating tubes sunk vertically into the ground the whole mass is converted into a solid frozen block, in which the shaft can be excavated as in rock. Cold appears to be the only agency which surely prevents decomposition and spontaneous explosion of guncotton and similar explosives. Hence the ammunition rooms of warships are always provided with refrigerating machines. In war, great storehouses equipped with refrigerating plants play a very important part. The transportation of live cattle in sufficient quantity to feed an army is now almost impossible, because of the congestion of the railways with freight of all kinds. A few statistics will illustrate the advantages secured by freezing. An ordinary freight car cannot carry more than twelve live cattle. A refrigerator car of the same size can carry the carcasses of 67 cattle, 350 hogs, and 694 sheep; that is to say, about 30,000 army rations. The frozen meat has the further advantage that it is ready to use and can be distributed immediately after arrival. The advantage of this method of provisioning troops was sufficiently proved in the Russo-Japanese and South African wars. Cold is a Protean thing which occasionally produces very astonishing results. Dry air is more favorable to combustion than damp air, but in order to dry the air there is no better method than to cool it and thus condense the moisture which it contains. Upon this principle is based a process of drying air in blast furnaces by means of cold, by which a saving of 20 per cent in fuel and a great increase in output are produced.

By cooling air to below —220 deg. F., liquid air, which is already used for many purposes, is produced. New applications of artificial cold are being brought to light almost daily.—Translated for the Scientific American Supplement from Umschau.

ANÆSTHETICS AND THE COIFFURE.

In his search for an easily drying wash for the hair the hairdresser appears to have been unfortunate as to the fluids which he has so far chosen for the purpose. The process involves the use of a preparation which, in the first place, must readily remove or dissolve greasy matters, and, secondly, which must be volatile in order more quickly to leave (this particularly in the case of women) the hair in a dry state. If we consult the category of articles which possess the dual property of being grease-removing and volatile we encounter at once such substances as ether, gasoline, benzine, chloroform, carbon tetrachloride, and so forth. In short, choice has to be made between a fluid which is highly inflammable or which is powerfully anæsthetic. In some cases the volatile substance is both anæsthetic and inflammable and the danger is twofold. Some years ago the light volatile hydrocarbons, of which gasoline and benzine are familiar examples, were in considerable use in the hairdressers' shops. Doubtless these are still used, but owing to the number of serious accidents which occurred, chiefly by the vapors of the hydrocarbons getting ignited even by an electric spark generated in the hair itself, or by a flame inadvertently brought near the hair still containing the inflammable fluid, their use became restricted unless very great care was taken to exclude the possibility of ignition. A comparatively non-inflammable yet volatile liquid was next tried, and although this avoided the ignition danger it introduced a new risk inasmuch as the heavy vapors which carbon tetrachloride (the substance referred to) gives off are very decidedly anæsthetic. In these columns some few years back we recorded a fatal case of anæsthesia produced by the use of tetrachloride as a dry hair-wash, and lately a similar case was reported in which it was shown that the same volatile liquid had been used for dry cleansing the hair, with the result that the victim, who, it was stated, suffered from a weak heart, died under the anæsthetic effects of the vapors. It seems to us that if the use of such washes for cleansing the hair is to be allowed at all, the process should be conducted in the presence of a person who has some expert knowledge of the dangerous properties of the cleanser; and it may be a counsel of perfection, but there can be little doubt that in the case just reported the deceased would probably not have lost her life if she had represented first to her medical man the kind of process to which she proposed to have her hair submitted. We doubt whether these dangerous dry hair-washes are necessary at all. Simple soap and water answer the purpose just as well, even with full, long hair, but the water *must be distilled*, and especially the water used for rinsing. A little pure spirit added to the rinsing water expedites the drying process and adds nothing by way of danger. A current of dry air completes the operation.—Lancet.

The recent series of experiments off Toulon to perfect a system of wireless telephony for the French navy appears to have demonstrated that wireless telegraphic emissions are not in any way able to disturb the transmission of messages by wireless telephony. Further experiments are to be conducted with a view to obtaining conclusive proof on this important point.

CANNING VEGETABLES IN THE HOME.*

SUGGESTIONS FOR THE HOUSEWIFE.

BY J. F. BREAZEALE.

ONE of the many problems that confront the American housewife is the supply of vegetables for her table during the winter months. "What can I have for dinner to-day?" is a question often heard. Since the advent of the modern greenhouse and the forcing of vegetables under glass, fresh vegetables can usually be found at any time in the markets of the large cities. But the cost of forcing vegetables or growing them out of season is and will continue to be very

FIG. 1.—ORDINARY SCREW-TOP JAR.

great. This makes the price so high as almost to prohibit their use by people of moderate means, except as a luxury. A healthful diet, however, must include vegetables, and therefore the housewife turns to canned goods as the only alternative. These are sometimes poor substitutes for the fresh article, especially the cheaper commercial grades, which necessarily lack the delicate flavor of the fresh vegetable. There is practically no danger, however, from contamination with tin or other metals providing the containers are made of proper materials and handled carefully. In some cases the proper care is not taken in packing vegetables for market. The decayed and refuse portions are not so carefully removed as they should be, and the requisite degree of cleanliness is not observed in their packing. Happily, however, such carelessness is not general.

Every housewife may run a miniature canning factory in her own kitchen, and on the farm this is especially economical and desirable, the economy being less pronounced in the case of city dwellers, who must buy their fruits and vegetables. Enough vegetables annually go to waste from the average farm garden to supply the table during the entire winter. But usually the farmer's wife cans her tomatoes, preserves her fruits, and leaves her most wholesome and nutritious vegetables to decay in the field, under the impression that it is impossible to keep them. This is a great mistake. It is just as easy to keep corn or string beans as it is to keep tomatoes, if you know how.

THE SCIENCE OF STERILIZATION.

The art of canning or preserving in one form or another is almost as old as history itself. The early

FIG. 2.—IMPROVED SCREW-TOP JAR.

Chinese possessed this secret long before the era of modern civilization, but "the reasons why" which lay back of the art have only recently been thoroughly explained.

The great secret of canning or preserving lies in complete sterilization. The air we breathe, the water we drink, all fruits and vegetables, are teeming with minute forms of life which we call bacteria, or molds, or germs. These germs are practically the sole cause of decomposition or rotting. The exclusion of air from canned articles, which was formerly supposed to be so important, is unnecessary provided the air is sterile or free from germs. The exclusion of air is necessary only because in excluding it we exclude the germ. In other words, air which has been sterilized or freed from germs by heat or mechanical means can be passed continuously over canned articles without affecting them in the least. If a glass bottle is filled with some vegetable which ordinarily spoils very rapidly—for instance, string beans—and, instead of cork, it is stoppered with a thick plug of raw cotton and heated until all germ life is destroyed, the beans will keep indefinitely. The air can readily pass in and out of the bottle through the plug of cotton, while the germs from the outside air cannot pass through, but are caught and held in its meshes. This shows that the germs and their spores or seeds are the only causes of spoilage that we have to deal with in canning.

Germs which cause decay may be divided into three classes—yeasts, molds, and bacteria. All three of these are themselves plants of a very low order, and all attack other plants of a higher order in somewhat the same way. Every housewife is familiar with the yeast plant and its habits. It thrives in substances containing sugar, which it decomposes or breaks up into carbonic acid and alcohol. This fact is made use of in bread making, as well as in the manufacture of distilled spirits. Yeasts are easily killed, so they can be left out of consideration in canning vegetables. Molds, like yeasts, thrive in mixtures containing sugar, as well as in acid vegetables, such as the tomato, where neither yeasts nor bacteria readily grow. Although more resistant to heat than yeasts, they are usually killed at the temperature of boiling water.

FIG. 3.—JAR WITH METAL LACQUERED TOP.

As a general rule, molds are likely to attack jellies and preserves and are not concerned with the spoiling of canned vegetables. The spoiling of vegetables is due primarily to bacteria.

Bacteria are also much more resistant to heat than yeasts. They thrive in products like milk and in meats and vegetables rich in protein, such as peas, beans, etc. All known species of molds require air in which to work. This is not true of bacteria, certain species of which will live and cause vegetables to decompose even when no air is present. When these particular species are present the exclusion of air is no safeguard against decay, unless the vegetable is first thoroughly sterilized. Bacteria are so small that they can only be seen with a microscope, and they reproduce themselves with amazing rapidity. One bacterium under favorable conditions will produce about twenty millions in the course of twenty-four hours. Accordingly certain vegetables spoil more rapidly than others, because they furnish a better medium for bacterial growth.

The reproduction of bacteria is brought about by one of two processes. The germ either divides itself into two parts, making two bacteria where one existed before, or else reproduces itself by means of spores. These spores may be compared to seeds of an ordinary plant, and they present the chief difficulty in canning vegetables. While the parent bacteria may be readily killed at the temperature of boiling water, the seeds retain their vitality for a long time even at that temperature, and upon cooling will germinate, and the newly-formed bacteria will begin their destructive work. Therefore it is necessary, in order to completely sterilize a vegetable, to heat it to the boiling point of water and keep it at that temperature for about one hour, upon two or three successive days, or else keep it at the temperature of boiling water for a long period of time—about five hours. The process of boiling upon successive days is the one that is always employed in scientific work and is much to be preferred. The boiling on the first day kills all the molds and practically all of the bacteria, but does not kill the spores or seeds.

As soon as the jar cools these seeds germinate and a fresh crop of bacteria begin work upon the vegetables. The boiling upon the second day kills this crop of bacteria before they have had time to develop

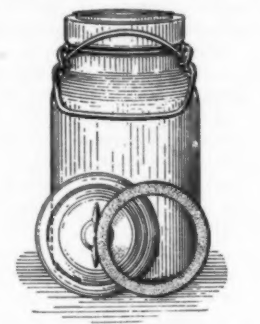


FIG. 4.—SPRING-TOP JAR.

spores. The boiling upon the third day is not always necessary, but is advisable in order to be sure that the sterilization is completed. Among scientists this is called fractional sterilization, and this principle constitutes the whole secret of canning. If the housewife will only bear this in mind she will be able with a little ingenuity to can any meat, fruit, or vegetable.

EXCLUSION OF THE AIR.

Even after sterilization is complete the work is not yet done. The spores of bacteria are so light that they float about in the air and settle upon almost everything. The air is alive with them. A bubble of air no larger than a pea may contain hundreds of them. Therefore it is necessary after sterilizing a jar of vegetables to exclude carefully all outside air. If one bacterium or one of its spores should get in and find a resting place, in the course of a few days the contents of the jar would spoil. This is why the exclusion of air is an important factor, not because the air itself does any damage, but because of the ever-present bacteria.

All of this may seem new fashioned and unnecessary to some housekeepers. The writer has often heard it said: "My grandmother never did this, and she was the most successful woman at canning that I ever knew." Possibly so, but it must be remembered that grandmother made her preserves—delicious they were, too—and canned her tomatoes, but did not attempt to keep the most nutritious and most delicately flavored vegetables, such as lima beans, string beans, okra, asparagus, or even corn.

SO-CALLED "PRESERVING POWDERS."

There are a great many brands of so-called "pre-

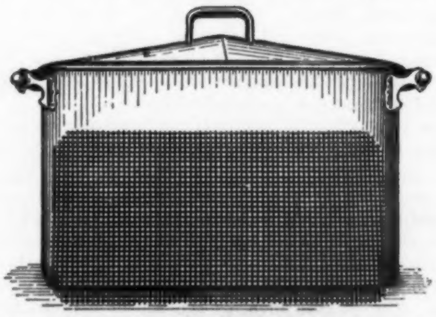


FIG. 5.—STERILIZER, SHOWING FALSE BOTTOM.

serving powders" on the market. These are sold not only under advertised trade names but by druggists and peddlers everywhere. In the directions for use the housewife is told to fill the jar with the fruit or vegetable to be canned, to cover with water, and to add a teaspoonful of the powder. It is true that these powders may prevent the decay of the fruit or vegetable, but they also encourage uncleanly, careless work, and in the hands of inexperienced persons may be dangerous. While with small doses the influence may not be apparent in an adult in normal health, with a child or an invalid the effect may be of a serious nature. The proper way to sterilize is by means of

* Reprint of Farmers' Bulletin 359, issued by the Department of Agriculture.

heat, and as this can be done very easily and cheaply the use of chemical preservatives in canning is not to be recommended.

KINDS OF JARS.

The first requisite for successful canning is a good jar. Glass is the most satisfactory. Tin is more or less soluble in the juices of fruits and vegetables. Even the most improved styles of tin cans which are lacquered on the inside to prevent the juice from coming in contact with the tin are open to this objection. While the amount of tin dissolved under these conditions is very small, enough does come through the lacquer and into the contents of the can to be detected in an ordinary analysis. While the small amount of tin may not be injurious, it gives an undesirable color to many canned articles. Tin cans cannot readily be used a second time, while glass with proper care will last indefinitely.

There are a great many kinds of glass jars on the market, many of them possessing certain distinct points of advantage. The ordinary screw-top jar is the one in most common use (Fig. 1). Although cheap in price, these jars are the most expensive in the long run. The tops last only a few years and, being cheaply made, the breakage is usually greater than that of a better grade of jar. The tops also furnish an excellent hiding place for germs, which makes sterilization very difficult. An improved type of screw-top jar is shown in Fig. 2. These are fitted with a glass top held in place by a metal cover which screws down over the neck of the jar. If the canning or sterilization is conducted properly, practically all of the air will be driven out of the jar by the steam. Upon cooling, this is condensed, a vacuum is formed on the inside which clamps down the glass top against the rubber ring and seals the jar automatically. The

Fig. 6.—STEAM COOKER.

metal cover can then be removed, as the pressure of the outside air will hold the glass top securely in place.

Another type of jar in common use is shown in Fig. 3. These require no rubber rings, but are fitted with a metal top, lacquered on both sides and having a groove around the lower edge. This groove contains a composition of the consistency of rubber which is melted during canning by the heat of the jar and forms a seal that takes the place of the rubber ring. These metal tops must be renewed each year, as it is necessary to puncture them in order to open the jar.

The most satisfactory jar that the writer has had any experience with is the one shown in Figs. 4, 7, 8, and 9. This has a rubber ring and glass top which is held in place by a simple wire spring. There are several brands of these jars on the market, so no difficulty should be experienced in obtaining them. Vegetables often spoil after being sterilized because of defective rubbers. It is poor economy to buy cheap rubbers or to use them a second time. As a general rule black rubbers are more durable than white ones.

Buy a good grade of jar. The best quality usually retails at from a dollar to a dollar and twenty-five cents a dozen. The initial expense may be, therefore, somewhat high, but with proper care they should last many years. The annual breakage should be less than 3 per cent on the average. In selecting a jar always give preference to those having wide mouths. In canning whole fruit or vegetables and in cleaning the jars the wide mouth will be found to be decidedly preferable.

CONTAINERS FOR STERILIZING.

The writer uses a tin clothes boiler with a false bottom made of wire netting cut to fit it (Fig. 5). The netting is made of medium-sized galvanized wire (No. 16) with one-half inch mesh. A false bottom is absolutely necessary, as the jars will break if set flat upon the bottom of the boiler. Narrow strips of wood, straw, or almost anything of this nature may be used for the purpose, but the wire gauze is clean and convenient.

There are several varieties of patent steamers or steam cookers in common use. These have either one

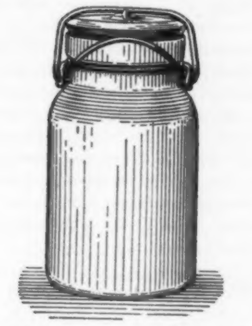


Fig. 7.—POSITION OF SPRING DURING STERILIZING.

or two doors and hold a dozen or more quart jars (Fig. 6). They are ideal for canning, but they are somewhat expensive and can be easily dispensed with. A common ham boiler or clothes boiler with a tight-fitting cover will answer every purpose.

SELECTION AND PREPARATION OF VEGETABLES.

The first step in successful canning is the selection and preparation of the vegetables. Never attempt to can any vegetable that has matured and commenced to harden or one that has begun to decay. As a general rule, young vegetables are superior in flavor and texture to the more mature ones. This is especially true of string beans, okra, and asparagus. Vegetables are better if gathered in the early morning while the dew is still on them. If it is impossible to can them immediately, do not allow them to wither, but put them in cold water or in a cold, damp place and keep them crisp until you are ready for them. Do your canning in a well-swept and well-dusted room. This will tend to reduce the number of spores floating about and lessen the chances of inoculation.

In the following pages are given directions for canning some of the more common vegetables, but the housewife can add to these at will. The principle of sterilization is the same for all meats, fruits, and vegetables.

Corn.

Contrary to the general opinion, corn is one of the easiest vegetables to can. The United States Department of Agriculture has shown that the amount of sugar in the sweet varieties diminishes very rapidly after the ear is pulled from the stalk; therefore in order to retain the original sweetness and flavor it is necessary to can corn very soon after it is pulled—within an hour if possible. Select the ears with full grains before they have begun to harden, as this is the period of greatest sugar content. Husk them and brush the silks off with a stiff brush. Shear off the grains with a sharp knife and pack the jar full. Add salt to taste (usually about a teaspoonful to the quart is sufficient), and fill up the jar to the top with cold water. Put the rubber ring around the neck of the jar and place the glass top on loosely, as shown in Fig. 7. Be careful not to press down the spring at the side of the jar.

Place the false bottom in the boiler and put in as many jars as the boiler will conveniently hold. Don't

Fig. 8.—POSITION OF SPRING AFTER STERILIZING.

try to crowd them in. Leave space between them. Pour in about three inches of cold water, or just enough to form steam and to prevent the boiler from going dry during the boiling. It is not necessary to have the water up to the neck of the jars, as the steam will do the cooking. Put the cover on the boiler and set it on the stove. Bring the water to a boil and keep it boiling for one hour. At the end of that time remove the cover of the boiler and allow the steam to escape. Press down the spring at the side of the jar, as shown in Fig. 8. This clamps on the top and will prevent any outside air from entering. The jars can now be removed and cooled or allowed to stand in the boiler until the next day.

On the second day raise the spring at the side of the jar, as shown in Fig. 7. This will relieve any pressure from steam that might accumulate inside the jar during the second cooking. Place the jars again in the boiler and boil for one hour. Clamp on the top as on the preceding day and allow them to cool. Repeat this operation on the third day. In removing the jars from the boiler be careful not to expose them to a draft of cold air while they are hot, as a sudden change in temperature is likely to crack them.

After the sterilization is complete the jars may be set aside for a day or two and then tested. This is done by releasing the spring at the side and picking up the jar by the top (Fig. 9). If there has been the least bit of decomposition, or if sterilization has not be complete, the top will come off. This is because the pressure on the top has been relieved by the gas formed by the bacteria. In this case it is always best to empty out the corn and fill up the jar with a fresh supply. If canning fruits or some expensive vegetable, however, examine the contents of the jar and, if the decomposition has not gone far enough to injure the flavor, place it once more in the boiler and sterilize over again. If the top does not come off, you may feel sure that the vegetable is keeping.

String Beans.

Select young and tender beans, string them, and break them into short lengths. Pack firmly in the jar, cover with cold water, and add a teaspoon of salt to each quart. Put on the rubber and top and boil for one hour on each of three successive days, as directed under "Corn." A small pod of red pepper placed in the bottom of the jar will give a delightful flavor to this vegetable.

Eggplant.

Pare the eggplant, cut in thin slices, and drop in boiling water for fifteen or twenty minutes. Drain off

Fig. 9.—MANNER OF TESTING.

the water and pack the slices in the jar. Cover with water and sterilize as directed under "Corn." The slices of eggplant are pliable and may be taken from the jar without being broken and either fried in bread crumbs or made into pudding and baked.

Beets.

Although beets will keep in the cellar over winter, it is very desirable to can them while they are young and tender, as the mature beet is apt to be stringy and lacking in flavor. Wash the young beets, cut off the tops, and put them in boiling water for about an hour and a half, or until they are thoroughly cooked. Take off the skins, cut in thin slices, and pack into the jars. Cover with water and sterilize in the manner previously described. If a mild pickle is desired, make a mixture of equal parts of water and good vinegar, sweeten to taste, and cover the beets with this mixture instead of water.

Okra or Gumbo.

This is a vegetable worthy of more extended culture. Although extensively grown in the South, it is comparatively unknown in the North. It is easily kept and makes a delicious vegetable for the winter. Wash the young and tender pods, cut them in short lengths, pack in the jars, cover with water, and sterilize. Okra is used for soups or stews.

Summer Squash.

Cut the vegetable into small blocks, pack in jars, and cover with water. Add a teaspoon of salt to each quart and sterilize. It is sometimes preferable with this vegetable, however, to pare off the skin, boil or steam until thoroughly done, mash them, and then pack in the jars and sterilize. If canned in the latter way, it is advisable to steam them for an hour and a half, instead of for an hour, on each of three days, as the heat penetrates the jar very slowly. It is absolutely necessary that the interior of the jar should reach the temperature of boiling water. A jar will

usually hold about twice as much of the cooked vegetable as it will of the uncooked.

English Peas.

When prepared and canned in the proper way, peas are easily kept and never lose the delicate flavor that they possess when fresh. Shell the young peas, pack in jars, and sterilize as directed under "Corn."

Asparagus.

Can the young tips only, in the same way as you would corn.

Cauliflower.

This vegetable usually keeps very well, but if the supply for the winter should begin to spoil it may be necessary to can it during the summer. Prepare it as you would for the table, pack it into jars, and sterilize.

Carrots and Parsnips.

These, if gathered during the early summer and canned, make most excellent vegetables for the winter. The young plants at that season are not stringy and have not yet developed the strong taste that is so objectionable to some people. Prepare as you would for the table, and sterilize.

Tomatoes.

Every housewife knows how to can tomatoes. They are very easily kept, even in the common screw-top jar. If one already has on hand a number of jars of this pattern, it is best to use them for preserves or for canning tomatoes and to purchase the more modern styles for canning other vegetables. In using the screw-top jars be careful to sterilize them first by placing in cold water, bringing to a boil, and boiling for about ten minutes. The rubber and top should also be immersed in boiling water for the same length of time. Remove them from the boiling water when needed, handling as little as possible. Be careful not to put the fingers on the inside of the top or the inner edge of the rubber. Fill the jar with the cooked tomatoes while steaming hot, put on the rubber, screw on the top firmly, invert it, and let it stand in that position until cool.

Kohl-rabi.

This vegetable resembles the turnip in its habits of growth, although in flavor it more nearly approaches the cauliflower. It is grown in many sections of the North, but in the South it is almost unknown. Prepare it as you would turnips, pack in the jar, and sterilize.

Lima Beans.

Lima beans lose their flavor very quickly after being shelled; therefore it is necessary to can them as soon as possible after gathering. Discard all pods that have begun to harden, and proceed as you would with corn.

Pumpkin or Winter Squash.

If provided with a warm, dry cellar, one may keep certain varieties of these vegetables all winter. Some of the best varieties, however, do not keep well, and even the best keepers when not properly housed begin to decay in December or January. It is then necessary to can them in order to save them. If one has a limited number of jars, it is a good plan to fill them all with other vegetables during the summer and upon the approach of frost to gather the pumpkins and bring them indoors. By the time the pumpkins begin to spoil, enough jars will be emptied to hold them. They can now be steamed and canned in the same way as summer squash. In this way a supply of jars may be made to do double service.

Succotash.

The writer has found that a mixture of corn and lima beans, or succotash, is one of the most difficult things to keep. This furnishes one of the very best mediums for bacterial growth; so extreme care must be taken in the process of canning. It is advisable to gather the corn and beans early in the morning and prepare and sterilize them in the manner already described. As with summer squash, it is best to boil for an hour and a half, instead of for an hour.

Vegetable Roast.

A rather unusual dish for the winter may be made by canning a mixture of vegetables. Prepare corn, lima beans, tomatoes, string beans, okra, squash, and eggplant as you would for canning separately. Mix these in varying proportions, letting the corn and lima beans predominate. Add two or three medium-sized onions to each quart of this mixture and run all through a food chopper in order to mix it thoroughly. Pack into jars and sterilize. In preparing for the table mix with an equal volume of bread crumbs, a piece of butter the size of a walnut, and one egg; season to taste with pepper and salt, and bake in a round baking dish until brown. Cut into slices as you would a cake and serve hot with a drawn butter sauce.

Corn, okra, and tomatoes, mixed in equal proportions, may be canned in this way as a soup stock.

FRESHNESS OF FLAVOR AND COLOR.

Vegetables when canned properly should retain their attractive color and lose very little of their flavor. It will be found almost impossible to detect any difference either in taste or in appearance between the canned and the fresh article if these directions are carefully followed. The volatile oils which give flavor to most vegetables are not lost during this process of sterilization. Cooking for *three short periods* in a *closed* container at a comparatively low temperature instead of cooking for one short period at a high temperature or for *one long period* in an *open* vessel makes the vital difference and insures freshness of flavor and color. After the jars have been sterilized and tested, they should be kept in the dark, as the sunlight will soon destroy the color of the vegetable.

HOW TO OPEN A JAR.

Jars of vegetables are sometimes hard to open, unless it is done in just the right way. Run a thin knife blade under the rubber, next to the jar, and press against it firmly. This will usually let in enough air to release the pressure on the top. In case it does not, place the jar in a deep saucepan of cold water, bring to a boil, and keep it boiling for a few minutes. The jar will then open easily.

CAUTIONS.

These directions for canning apply only to pint and quart jars. If half-gallon jars are used, always increase the time of boiling, making it an hour and a half instead of one hour.

Do not go into canning too deeply at first. Experiment with a few jars in the early part of the season and see if they keep well. It is not a difficult matter to can vegetables properly. The writer has never lost a can of string beans, okra, eggplant, carrots, parsnips, lima beans, beets, asparagus, or pumpkin in several years' experience, and has had only one can of peas spoil, a few cans of corn during the earlier trials, and a few cans of succotash. Any housewife can do equally well. If you follow the directions here given carefully, you will have no difficulty whatever. If you should happen to fail in the first trial, rest assured you have done something wrong or left something undone. No housewife who has on hand during the winter a supply of home-canned vegetables ready to serve on ten minutes' notice will ever regret the trouble or difficulties experienced in learning.

THE LESSON OF EVOLUTION.*

DARWIN AND HIS MESSAGE.

BY PROF. E. H. STARLING.

Just as pain is the great educator of the individual and is responsible for the laying down of the nervous paths, which will determine his whole future conduct and the control of his lower by his higher centers, so hardship has acted as the integrator of nations. It is possible that some such factor with its attendant risks of extermination may still be necessary before we attain the unification of the British Empire, which would seem to be a necessary condition for its future success. But if only our countrymen can read the lesson of evolution and are endowed with sufficient foresight, there is no reason why they should not, by associating themselves into a great community, avoid the lesson of the rod. Such a community, if imbued by a spirit of service and guided by exact knowledge, might be successful above all others. In this community not only must there be subordination of individual to communal interests, but the behavior of the community as a whole must be determined by anticipation of events—i. e., by the systematized knowledge which we call science. The universities of a nation must be like the eyes of an animal, and the messages that these universities have to deliver must serve for the guidance and direction of the whole community.

This does not imply that the scientific men, who compose the universities and are the sense organs of the community, should be also the rulers. The reactions of a man or of a higher mammal are not determined immediately by impulses coming from his eyes or ears, but are guided by these in association with, and after they have been weighed against, a rich web of past experience, the organ of which is the higher brain. It is this organ which, as the statesman of the cell community, exercises absolute control. And it is well that those who predicate an absolute equality or identity among all the units of a community should remember that, although all parts of the body are active and have their part to play in the common work, there is hierarchy in the tissues—different grades in their value and in their conditions. Thus every nutritional mechanism of the body is subordinate to the needs of the guiding cells of the brain. If an animal be starved, its tissues waste; first its fat goes, then its muscles, then its skeletal structures, finally even the heart. The brain is supplied with oxygen and nourishment up to the last. When this, too, fails, the animal dies. The leading cells have first call on the resources of the body. Their needs, however, are soon satisfied, and the actual amount of food or oxygen used by them is insignificant as compared with the greedy demands of a working muscle or gland cell. In like manner every community, if it is to succeed, must be governed, and all its resources controlled by men with foreseeing power and rich experience—i. e., with the wisdom that will enable them to profit by the teachings of science, so that every part of the organism may be put into such a condition as to do its optimum of work for the community as a whole.

At the present time it seems to me that, although it is the fashion to acquiesce in evolution because it is accepted by biologists, we do not sufficiently realize the importance of this principle in our daily life, or its value as a guide to conduct and policy. It is probable that this doctrine had more influence on the behavior of thinking men in the period of storm and controversy which followed its promulgation fifty years ago, than it has at the present day of lukewarm emotions and second-hand opinions. Yet, according to their agreement with biological laws, the political theories of to-day must stand or fall. It is true that in most of them the doctrine of evolution is invoked as supporting one or other of their chief tenets. The socialist has grasped the all-importance of the spirit of service, of the subordination of the individual to the community. The aristocrat, in theory at any rate, would emphasize the necessity of placing the ruling power in the hands of the individuals most highly endowed with intelligence and with experience in the affairs of nations. He also appreciates the necessity of complete control of all parts by the central government, though in many cases the sense organs which he uses for guidance are the traditions of past experience rather than the science of to-day. The liberal or individualist asserts the necessity of giving to each individual equal opportunities, so that there may be a free fight between all individuals in which only the most highly gifted will survive. It might be possible for another Darwin to give us a politic which would combine what is true in each of these rival theories, and would be in strict accord with our knowledge of the history of the race and of mankind. As a matter of fact the affairs of our states are not determined according to any of these theories, but by politicians, whose measures for the conduct of the community depend in the last resort on the suffrages of their electors—i. e., on the favor of the people as a whole. It has been rightly said that every nation has the government which it deserves. Hence it is all-important that the people themselves should realize the meaning of the message which Darwin delivered fifty years ago. On the choice of the people, not of its politicians, on its power to foresee and to realize the laws which determine success in the struggle for existence, depends the future of our race. It is the people that must elect men as rulers in virtue of their wisdom rather than of their promises. It is the people that must insist on the provision of the organs of foresight, the workshops of exact knowledge. It is the individual who must be prepared to give up his own freedom and ease for the welfare of the community.

Whether our type is the one that will give birth to the super-man it is impossible to foresee. There are, however, two alternatives before us. As incoherent units we may acquiesce in an existence subordinate to or parasitic on any type which may happen to achieve success, or as members of a great organized community we may make a bid for determining the future of the world and for securing the dominance of our race, our thoughts and ideals.

* Abstract of a paper read before the British Association for the Advancement of Science.

IMPORTANCE OF FERMENTS IN ORGANIC LIFE.

THEIR CATALYTIC EFFECT.

BY DR. A. ZART.

Ferments, or enzymes, belong to the class of substances called catalyzers, which play in chemical reactions a part analogous to that of brokers in business life. A few simple examples from inorganic chemistry will make clear the meaning of this statement. In the self-lighting gas burner, a mass of finely-divided platinum, called spongy platinum, is placed immediately above the gas jet. When the gas is turned on the metal becomes heated gradually to redness, and finally the gas is ignited. The puzzling part of this phenomenon is the heating of the platinum. The friction of the current of gas is not sufficient to account for it. We must therefore seek a chemical explanation. Illuminating gas is composed chiefly of hydrogen and hydrocarbons, both of which are combustible, that is to say, they combine with oxygen, when heated to a sufficiently high temperature. Every combustible substance has its own characteristic temperature of ignition. The function of the spongy platinum in the self-lighting gas burner is to lower the temperature of ignition. The first action is a combination of platinum with the oxygen of the air. In this the oxygen is very loosely combined, so that even at ordinary temperatures it escapes from the combination with platinum and unites with the hydrogen which surrounds it. In this combination carbon dioxide and water are formed and a certain amount of heat is produced. Hence the platinum becomes hot, the chemical actions above described are intensified by the rise in temperature, and heat is produced more rapidly, until finally the platinum becomes incandescent and ignites the stream of gas.

Now let us regard the process of combustion as it takes place in the human body. The fuel is derived from the food and oxygen is brought in through the lungs. The role of the platinum in the gas burner is assumed in the human body by a class of ferments known as oxydases, which are produced by the organism itself. By the agency of these ferments the energy contained in the food is converted into heat and work by means of combination with oxygen.

The water which is formed by the combination of hydrogen and oxygen always contains the same proportion of the two gases, but in certain conditions a compound is formed which contains twice as much oxygen as water contains. This compound is called hydrogen dioxide. It readily gives up the extra portion of oxygen, with evolution of heat, but its aqueous solution is fairly permanent. If a piece of platinum is dipped into a solution of hydrogen dioxide a lively evolution of gas is produced. The platinum first combines with the hydrogen dioxide, forming a very unstable compound, from which some of the oxygen readily escapes.

The most interesting peculiarity of all catalyzers, including ferments, is this: The amount of chemical change produced bears no definite relation to the quantity of catalyzer present. Platinum, for example, can ignite a thousand or a million times its mass of gas, or decompose equally enormous quantities of hydrogen dioxide, without losing any of its catalyzing power. Catalyzers, in addition to causing chemical reactions, are able to accelerate or retard such reactions, according to circumstances. Animal bodies contain such agents in great variety and of highly specialized character. In order to follow these mysterious chemists in their work in the laboratory of the body we will endeavor to trace the history of a piece of bread and butter after it is swallowed. The morsel consists chiefly of starch, fat, and albuminous substances. Starch is a very complex substance, nearly related to sugar. In the digestive canal it is acted upon successively by a series of ferments, which are called diastases. The attack is begun in the mouth by the ptyalin secreted by the salivary glands, which converts part of the starch into dextrin or gum and maltose or malt sugar. In the upper part of the small intestine the attack is continued by the diastase secreted by the pancreas, which converts the starch entirely into maltose. The maltose is finally transformed into glucose, or grape sugar, by a special ferment, maltase, contained in the intestinal fluid. Cane sugar, if present in the food, is converted into a mixture of grape sugar and fruit sugar (dextrose and levulose) by yet another ferment, called invertin. The sugars, being soluble, pass through the walls of the intestine into the blood and are carried to the liver, where they are, so to speak, checked. For health it is necessary that the quantity of sugar which passes through the liver shall be just sufficient to give the blood a definite small percentage of sugar. Any excess of sugar which reaches the liver is there transformed, chiefly into a special form of starch, called glycogen, which is stored up for future use. When required, the glycogen is again converted into sugar by diastatic ferments. The further transformations which starchy food undergoes in the body are also carried out by the agency of ferments. The final products, as in combustion in the air, are carbon dioxide and water.

The history of the fatty portions of the food is similar to the above. By the action of a special ferment, lipase, in the intestinal canal, the fats are decomposed into their constituents, fatty acids and glycerin, which are again combined into a form peculiar to the human species by another ferment which has not been isolated. Fat, which is the most valuable fuel combined in our food, is finally oxidized by other special ferments, the action of which is analogous to that of spongy platinum.

The albumen of the food is decomposed by the successive action of three ferments. The first of these is pepsin, secreted by certain glands of the stomach and soluble only in acids. The second is trypsin, which is secreted by the pancreas and requires a neutral or slightly alkaline liquid for its solution. The third is erepsin, which is produced in the small intestine. The name albumen includes a number of extremely complex substances, all of which, however, may be divided into essentially the same constituents, which belong to the class of the amino acids and their substitution products. We cannot here go into the chemistry of these substances, of which about seventeen varieties are known. They are capable of combining with each other in very different groupings and proportions. If we imagine a child's box of building blocks, containing seventeen different kinds of blocks and a great number of blocks of each kind, the possibilities of variation of structure in the compounds of the amino acids become apparent.

The pepsin and hydrochloric acid of the gastric juice divide the albumen of the food into simpler but still complex bodies, called peptones, which possess many of the characteristics of albumen. The trypsin in the intestine goes further. It also first produces peptones, but it converts these partially into the simpler amino acids. The work is completed by the erepsin, which leaves nothing but amino acids. These are absorbed through the walls of the intestine and immediately converted by other special ferments into compounds peculiar to the species and the individual.

At this point our exact knowledge ends. Diastatic, lipolytic, and proteolytic ferments, that is to say, ferments which decompose and dissolve starch, fat, and albumen respectively, have been found in every part of the body. Constructive ferments are also present. It appears as if every single cell of the body produces its own ferments.

Plants also make use of ferments in their nutrition. The young seedling draws first on the supply of food stored up in the seed. This food must be prepared for assimilation. The starches are dissolved by diastase, the albumen is split up by proteolytic ferments, and the fats are saponified by lipases. The seeds of the castor oil plant contain so much lipase that they are used industrially for saponifying fats in soap making. The diastase of sprouting barley is used to convert starch into sugar in the brewing and distilling industries. A diastatic ferment has also been found in the leaves of plants. This ferment, which is most abundant at night, serves to convert into sugar, and hence make soluble and portable, the starch which has been formed in the leaf during the day. In the formation of starch by leaves we find a ferment action which is entirely wanting in the animal organism. Our ferments confine their activities to converting into heat the energy stored in chemical compounds, but the chlorophyl of plants, with the aid of sunlight, builds up the compounds which supply this energy.

The classical example of the action of ferments is found in the alcoholic fermentation, which is brought about by a minute fungus, the yeast plant. It was long believed that fermentation could take place only under the influence of the living yeast plant. This belief was shattered when Buchner and Hahn expressed from yeast a lifeless organic compound which, independently of the living cell and its vital activities, possesses the power of decomposing sugar into alcohol and carbon dioxide. Similarly, Buchner and Meisenheimer obtained from the bacteria of the acetic fermentation a chemical ferment which converts alcohol into acetic acid in the presence of oxygen. Very little is known of the chemical nature of all these ferments, or enzymes, but they are assumed to be somewhat analogous in composition to albumen. We can recognize the ferments only by their actions. Their origin is also unknown. We know only that they are produced in the cells, or elements of which every organic living body is composed, and that they produce their effects either inside or outside the cells. At first, however, they are secreted in an inactive condition, which is converted into an active state by the influence of some other substance, at the place of use. For example, pepsin acquires its activity in the stomach by admixture with hydrochloric acid. The diastase of the pancreas acquires its property of decomposing starch by admixture with other substances in the intestine. Thus the body is able to restrict the activity of its ferments to particular localities. Furthermore, the organism is able to produce ferments as they are needed. For example, mold fungi, cultivated on albumen, produce proteolytic ferments, while on starch they secrete diastases. If a barley sprout is fed sufficiently with syrup it ceases to produce the diastase required to convert the starch of the kernel into sugar. In connection with the specializing of ferments it is of interest to note that the same substance, grape sugar, is converted by one ferment into butyric acid, carbon dioxide, and hydrogen, by another into lactic acid, and by a third into alcohol and carbon dioxide.

The importance of ferments in human life is shown by the evil consequences which follow the cessation of their activity. In the disease known as diabetes the ferments of the liver apparently lose their control over the sugar, and the oxidizing ferments also fail in their task, so that the whole body is saturated with sugar, of which more than two pounds are sometimes daily excreted through the kidneys. Many cases of poisoning, also, are simply the result of paralysis of the ferments.

In this brief sketch many important things have been passed over, including the ferments involved in the metabolism of nuclein, the material of the nuclei of the cells, and the experiments which have been made with constructive ferments, but enough has been said to give an idea of the intimate connection which exists between ferments and organic life.—Translated for the Scientific American Supplement from Kosmos.

A KINEMATIC ILLUSION.

In a recent issue of Nature W. B. Croft calls attention to a curious kinematic illusion. People are sometimes amazed by noticing that in a motor car seen through railings the wheels appear to revolve the wrong way.

As the eye follows the moving objects it is convenient to imagine that the car, which may be actually running to the right, is stationary, while a vertical rail is moving past it to the left with an equal velocity. The apparent intersection of this rail with the upper edge of the wheel is a point running round in a contrary direction to that of the rotation of the wheel. This moving point suggests rotation of the wheel. When oblique lines swing in front of vertical lines the movement of the intersections is curious to watch. It is true that the lower half of the wheel goes against our theory, but at a given moment its effect may be less noticeable, either from being hidden in dust or because the eye has a very small range of close attention. Mr. Croft states that he has seen the appearance, and has had reports of it from others, but cannot speak with precision as to the condition of seeing it effectively.

It is common to rotate vacuum tubes while a discontinuous spark illumines them. A spark may pass at the instant of starting one revolution, and the illumination may recur slightly before or after the beginning of a second round; in either case there is a false suggestion as to the rotation. The railings would make discontinuous vision of the spokes of the motor wheels, and a spoke might be seen upright in one gap but at slightly different angles at other gaps.

THE CASTING OF BRONZE STATUES.

THE GENERAL SHERIDAN STATUE.

Concluded from Front Page.

stoned and the drag of the mold is filled with this same special molding sand, being rammed down and strengthened with jaggers until the drag is full. It is next necessary to turn over the entire mold with all the parts in place, and then to remove the cope with its preliminary sand filling, and by repeating the process of making a complete set of little cores for this other side of the plaster figure, the cope of the mold is made in the same way.

Now when the mold is taken apart by lifting off the cope the sand will come away from the pattern and little cores, leaving all these little cores still in place against the plaster pattern. The cope is turned over, and each little core is then lifted out separately from its place on the pattern and placed other side up in its own print in the cope, which was formed by the ramming up of the sand in the cope. It will be seen that when all these little cores have been put into the cope their exposed surfaces will form the exact reverse of the plaster pattern, no matter how many undercut portions there were in the drapery of the figure or in the features of the body. The drag is then removed from the other side of the pattern, and after turning over, its own cores are set back into their prints, just as was done for the cope. When all the cores are in place in both the cope and the drag, the mold is complete in every exterior detail, being an exact reproduction of the plaster cast, only, of course, in the reverse.

FIG. 3.—STERLING SILVER STATUE OF COLUMBUS 8 FEET HIGH, SHOWING "GRAPEVINE" BEFORE CLEANING.

THE CASTING OF BRONZE STATUES.

THE INSIDE CORE.

Everybody knows that bronze statues are hollow, and when in ordinary sizes they are not much more than $\frac{1}{4}$ or $\frac{3}{8}$ inch thick, and as these hollow parts extend throughout the statue, it may be imagined that this core work is also quite complicated. In spite of this it can be again stated that absolutely no core box is used even to furnish the complicated core of the inside of a statue.

In order to make the main core of the statue, the completed mold, bolted together with all its little cores in place, but without the plaster pattern, is carefully filled with the molding sand, and this sand is rammed in from a suitable opening, usually at the bottom of the figure, an iron framework, called the "armature," being used to stiffen the core. This operation forms a complete sand figure, an exact reproduction of the plaster pattern, right side before and of the same size. The mold is next carefully taken apart, and, of course, the little loose cores inside will come away, attaching themselves to the main inside core by means of the various undercut sections. These little cores are then carefully removed from the main core and placed back into the two halves of the mold, leaving the main core a complete figure.

This main core is next covered over with soapstone, and the molder uses a small, sharp knife to go over the entire surface of the main core, shaving away a thickness of sand equal to the thickness of metal desired in the finished statue. The soapstone coating helps to guide him so that he can tell just what parts have been shaved and which parts have not. This leaves a complete sand figure similar to the plaster pattern, with the exception that it is smaller in every direction by an amount equal to twice the thickness of the metal, and, of course, in this process of shaving many of the details have been eliminated, as these details are not at all necessary on the inside of the statue, which nobody can see. Fig. 4 shows the loose corework, and at the left center of the picture a workman is constructing a wire armature for an inside core to fill an outside loose core.

In order to support the main core inside of the mold steel pins are run into the core right on the parting line of the main mold, so that the core is supported at various points on the parting line. These steel pins differ from chaplets, in that the pins will stick through the bronze, projecting from both sides of the metal. After the metal has been poured and cooled, these pins are pulled out by main force and the small holes are plugged up with bronze and finished over the outside surfaces so as to be entirely hidden. It is not possible to use bronze chaplets, because being so small and melting at a comparatively low temperature they would melt down almost as soon as the main body of hot metal struck them, which would, of course, allow the core to drop down out of place.

The inside surfaces of the mold are next given a coat of blacking and the mold is then put into a hot oven where, with an intense heat of long duration, every particle of moisture is driven from the sand. In statue work it is absolutely essential that the molten metal be forced into intimate contact with the sand, because the surface of the mold has in it all the various marks, indentations and scorings given by the artist, in order to represent folds, creasings, and even the fabric out of which the draperies are supposed to be made. The baking for such a long period is to insure that the metal shall come into this intimate contact with the sand by the removal of all the moisture, and as the pouring is done while the sand is still hot, chilling of the metal is to some extent prevented.

"THE GRAPEVINE."

With castings having walls so thin as these statues and spread over so large a surface in comparison to their weight, it is necessary to take still other precautions to insure that the metal will reach every part of the mold before it chills. To insure this there are many gates and passages leading through the mold to all parts of the statue. This is shown in a remarkable way in Fig. 3, which shows a sterling-silver statue of Columbus 8 feet high just after it was taken from the mold and before trimming. Some few of the metal parts shown around this statue are braces in the mold to hold the sand and support the inside core, but by far the greater portion, the "grapevine," as it is called, is composed of these gates and passages leading from the pouring gate to every part of the mold.

To further insure that every part shall be filled, and also again to bring the metal into intimate contact with the sand, a considerable hydrostatic head of metal is provided by a reservoir elevated some little distance above the mold, this reservoir being full of molten metal while it is flowing into the mold, and during solidification. The large body of metal in the grapevine and in the reservoir also insures freedom from shrinkage cracks. As the metal chills, it of course shrinks, and if it were thin, as in the statue itself, there would not be enough metal to draw upon to prevent it from pulling apart. However, the comparatively heavy parts of the grapevine contain a considerable body of metal, and although this hardens on the outside, the center of each one of these metal ducts will remain molten, and as the air rises it can be seen that as shrinkage takes place the still molten metal in the center of these ducts and gates draws down, tending to keep the molds completely full. An imperfect casting is, of course, an expensive thing, and special skill and pains are required of the molder to insure that the casting will be complete and perfect when taken from the mold.

THE JOINTS.

As already intimated, some parts of certain statues which project too much to be conveniently cast in one piece are cast separate from the main body. Sometimes the heads are cast separate, and nearly always parts of the arms and legs, although as already said in the case of the Sheridan statue, the horse, which under ordinary circumstances would be cast in eight pieces, was made in one.

To make the joints in the statues brazing or welding has not yet been successfully accomplished, because the bronze when hot is very brittle. Soldered joints are imperfect and difficult to hide, and for this reason the only alternative left is skillful mortise-and-tenon work. Suppose, for instance, that a head is to be attached to a statue by this mortise-and-tenon method, the portion of the body around the collar would be cast with a taper flange turned in, and the These holes are drilled on angles such that when bronze pins are driven tightly into the holes the tendency is to wedge all the parts rigidly into place. When the bronze pins have been driven home, the ends are cut off, filed and chased to represent the rest of the surface of the statue, and it is next to impossible to discover where they are located. This, then, describes the method of casting bronze statues in sand which is in general use.

cores, how do they get the mold apart to remove the wax pattern without spoiling the mold? The way to do this is to put the whole mold, with its core and the wax figure, into the oven and bake it for a long time at a high temperature. This naturally melts out the wax, which runs down out of the mold, leaving the sand in place, and when the bronze is poured into this mold, the surface of the statue resulting will be just exactly what the artist produced when he went

FIG 4.—INTRICATE CORE WORK MADE WITHOUT CORE BOXES.

head, or rather the neck, would be continued in a tapered extension to exactly fit the taper of the turned-in flange.

The two tapers are cast from the same pattern by the core method already described, but it necessarily does not form an exact fit, and very often there are some rough spots on the parts. It is essential, however, that these two parts shall exactly fit, and this is accomplished by white-leading the parts, placing them together, noting the high spots, as shown in the white lead, and then filing and scraping off these high spots one after another until the parts come together perfectly. It may take several days to make such a joint as this, but when properly done it is practically impossible of detection by the naked eye. It is usually so arranged also, that the line of parting is made at some point where it will not show, due to a wrinkle in the flesh, or in the drapery, as the case may be. It is, however, almost impossible

THE LOST WAX PROCESS.

There is another process known as the "lost wax process," which it is said is one of the oldest methods of making statues, and which is also practised in a modified form for certain classes of work at the present time. The object of the lost wax process is to give the artist something to retouch just previous to the pouring of the metal, and also to avoid the small fins at the core partings.

To do this the mold is made up in practically the same way as already described for the sand process, and the usual French molding sand is used. The cores are all put in, including the main inside core, and then melted beeswax, instead of metal, is poured into the mold, giving a figure, the core of which is made of sand and the surface of beeswax. The artist may then go over the beeswax surface, removing the fins and changing the details to bring out the effects desired as much as he may see fit.

over the wax figure. Also there will be a complete absence of all the small fins, which are necessarily left by the many little loose cores of the ordinary sand process. It should be remarked, however, that these little fins are very easily chipped and filed away, and when the statue is finished they do not show at all.

While this wax process is supposed to give a very fine surface to the statue, it is claimed by the manufacturers that they can do just about as well with the ordinary sand mold and its little removable cores as can be done with the "lost wax process," and at the same time do it much cheaper. This process is not used to any great extent, except as already said for certain classes of very fine work, and even here its usefulness is doubtful.

THE WASHED-CLAY PROCESS.

All of this discussion has dealt with figures, but as is well known there is another form of bronze work,

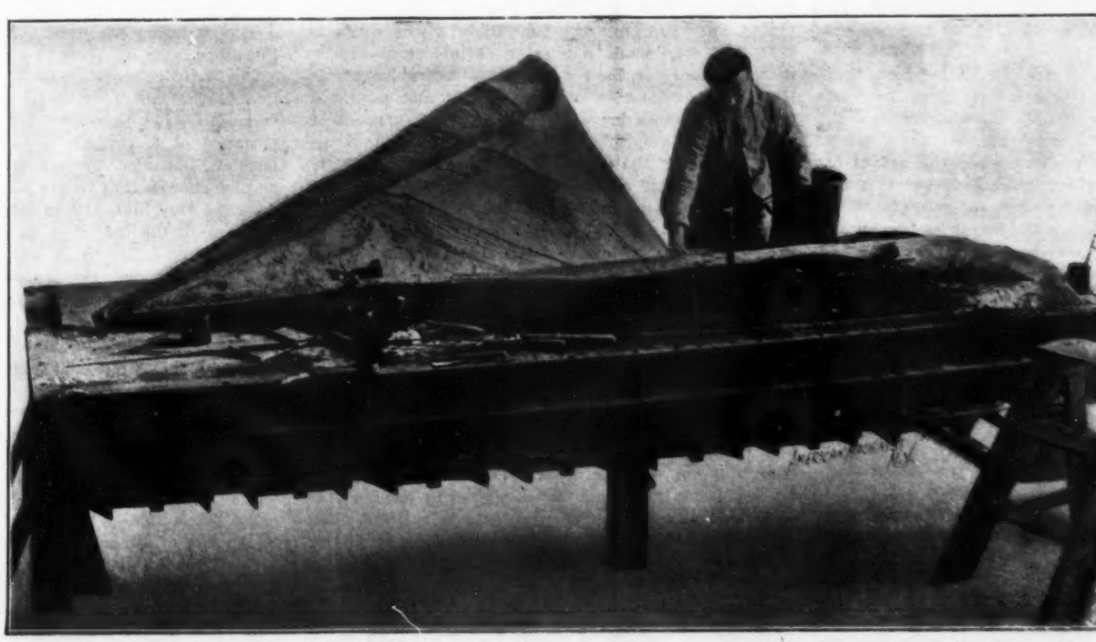


FIG. 5.—THE FIRST OPERATION: BUILDING THE SAND AROUND THE PLASTER PATTERN.

THE CASTING OF BRONZE STATUES.

to discover these joints even when there is nothing to hide them except the skill of the mechanic.

So much for the fitting together, but it is of course necessary to hold the parts rigidly in place so that they cannot fall out, or become in the slightest degree misplaced. To hold the parts together they are forced strongly into place, and then holes are drilled through the outside of the statue, passing through the two inside flanges and locking the whole thing together.

When this has been done the outside molds are thrown away, including all their little loose cores, and the wax figure, with its sand core, is rammed up into a new sand mold, which will, of course, take exactly the form of the wax figure, and in this stage of the process none of the little loose sand cores are used, as the sand of the main mold fills in all the depressions and undercuts.

The question now arises, if there are no little loose

such as medallions, tablets, etc., containing sometimes a raised scroll work, but very often a relief of the human figure. The patterns in this case also are usually of plaster, and if there are any undercut parts they are taken care of by the little loose cores, as already described.

If the backs of these tablets are examined it will be found that the surface corresponds more or less with the front surface and that the metal is nearly

of a uniform thickness all over. To do this with a pattern having only one face and that the finished side, the mold of the front side is made, usually in plaster. Then all the depressions of the plaster mold are filled in with a thin layer of clay, this layer of clay being as thick as the thickness of metal desired.

When the depressions have thus been made shallower by the amount of the thickness of the clay, the other half of the mold is poured over in plaster, filling all the depressions down to the clay surface. Then by lifting off the new plaster half of the mold and removing the clay, it will be found that there is a complete mold formed which will give a thickness of metal exactly equal to the thickness of the clay. The clay is removed by washing, and this process is known as the washed-clay process.

In all of this work the halves of the molds are held in place by shallow mortise-and-tenon joints in the sand of the sand molds and in the plaster of the plaster molds because the registering of the two halves of the mold must be of far greater accuracy than can be produced by the ordinary flask dowel pins. Venting is taken care of much the same as with iron, except that there is very little gas to be carried off and there are no coke beds or cores used. The main core is usually vented in one or two places by the insertion of perforated piping leading to the outside.

A SKETCH OF THE HISTORY OF PROPELLANTS.*

THE RISE OF EXPLOSIVES.

BY SIR ANDREW NOBLE, BART., K.C.B., F.R.S., D.SC.

I purpose, in this paper, to give a sketch of the history of propellants, pointing out how gunpowder for many centuries was the sole propellant employed, and which remained during these centuries with the mode of manufacture unimproved, while, even by very great men, the wildest and most divergent ideas were entertained as to the pressures developed by its explosion, and the energy which it was possible to realize.

The origin of gunpowder is, I am afraid, lost in remote antiquity. It was supposed to have been known, though not as a propellant, in China before the Christian era, but it was certainly known to Roger Bacon about 1265, who also was the first to suggest its use for military purposes. Its first employment in war was in the fourteenth century, and its composition and mode of manufacture during many centuries seem to have undergone but little change or improvement.

In England gunpowder consisted of 75 per cent of saltpeter, 15 per cent of carbon, and 10 per cent of sulphur, while in France and some other countries the carbon and sulphur were in equal proportions, viz., about 12.5 per cent.

These differences in proportions affected but slightly the energies and pressures developed by fired gunpowder, but I do not know any physical fact with regard to which such wide differences of opinion were entertained by the many eminent men who have written upon the subject.

De la Hire, the first writer on gunpowder, in 1702, supposed that the propelling force of gunpowder was due to the elasticity of the air between the grains, and that the function of the powder was merely that of a heating agent.

Robins, however, who in 1743 read before the Royal Society of London a paper in which he described his experiments, pointed out that he had found that at ordinary temperatures and atmospheric pressure the generated gas occupied about 236 times the volume of the gunpowder, and that at the temperature of explosion—which, however, he much underestimated—the maximum pressure would be about 1,000 atmospheres (6.6 tons per square inch).

He considered, and cited experiments to prove, that the whole of the powder he employed must be fired before the projectile was sensibly moved from its seat, his argument being that, were this not so, a much greater energy would be realized when the weight of the projectile was materially increased; but this experiment showed that this was not so.

Hutton, in 1778, read before the Royal Society an account of his celebrated researches in gunnery, and detailed the experiments from which he deduced the maximum pressure of gunpowder to be about twice that given by Robins, or about 2,000 atmospheres.

Hutton, like Robins, saw that the energy of gunpowder was due to the elasticity of the highly heated gases generated by the explosion and, assuming that the powder was instantaneously ignited and that the pressure was as he stated, gave formulæ for deducing the pressure of the gas and the velocity of the projectile at any point of the bore.

In 1797 Count Rumford communicated to the Royal Society his celebrated experiments on gunpowder, and these remained for many years the only experiments from which the pressure was deduced by actual measurement. In Rumford's case the weight lifted by the pressure of the exploded powder was assumed to be the correct measure of the pressure.

Rumford made two series of experiments, but the charges he employed were very small, his largest, with the exception of one by which his vessel was destroyed, being 18 grains or about 1¼ grammes.

From the first series Rumford deduced that with a charge at a density of unity the pressure would reach 29,000 atmospheres. But, high as this result is, Rumford considered it much too low, and from a second series, the results of which were very discordant, he arrived at the conclusion that the tension of exploded gunpowder such as he employed, when filling completely the space at which it was inclosed, was about 101,000 atmospheres.

I may observe that the mode of firing the powder which Rumford was compelled to adopt, viz., the heating of the vessel in which the powder was confined by a red-hot ball, would materially increase the pressure, and he further accounted for the enormous pressures he gave not being realized in guns, by assuming that the combustion of powder in artillery and small arms was comparatively slow and approximated to the rate of combustion in the open air. From an examination, however, of Rumford's apparatus it is not difficult to conjecture both how he supposed his pressures to be so high, and also how some of his results were so discordant.

Passing over several experimenters or writers on the subject, I must refer to the researches of Bunsen and Shischkoff, who in 1857 published the results of their important investigations. The powder in their experiments was not exploded, but deflagrated by being allowed to fall in an attenuated stream into a heated bulb, in which, and in the connected tubes, the products of combustion were collected.

The transformation under these conditions would not be quite the same as if the powder had been exploded under pressure, but a careful analysis was made both of the solid products and of the gases. The weight of the permanent gases found by them represented only 31 per cent of the weight of the powder, and occupied at 0 deg. C. at atmospheric pressure only 193 times the volume of the unexploded powder. They fixed the temperature of explosion at 3,340 deg. C. and computed that the maximum pressure which the gas can attain, which it may approximate to but can hardly reach, is about 4,374 atmospheres, or 29 tons on the square inch.

The very high tension of 101,000 atmospheres suggested by Count Rumford as the result of his latest experiments does not appear ever to have been accepted, but within my own time Piobert, who wrote in 1864, and who made a number of important experiments, appears to have accepted as tolerably correct Rumford's first series of experiments, and fixed the tension of gunpowder when fired in its own space at about 23,000 atmospheres, while Cavalli in 1867 arrived at nearly the same conclusion, making the tension about 24,000 atmospheres. On the other hand, I find that text-books in use at the Royal Military Academy, Woolwich, so late as 1879 placed the tension of fired gunpowder so low as 2,200 atmospheres, or, say, about 14 tons per square inch.

The authors who ascribed the enormous pressures I have named much underrated the rapidity of the combustion of gunpowder under pressure, and assumed that the combustion was comparatively very slow, and that due to this slow combustion the possible maximum pressure was never even approximated to in the bores of guns; but it has always struck me as remarkable that the authorities who accepted these high tensions did not test the accuracy of their assumptions by employing the simple test suggested by Robins, viz., to find what increase of energy would be realized when the weight of the shot was doubled, trebled, etc.

I myself, about a century and a half after Robins, repeated his experiment with means at my disposal far greater and more accurate than anything he could have employed, and the result with the old R. L. G. powder was as follows:

In a 6-inch gun with a shot weighing 30 pounds the initial velocity was 2,126 foot-seconds, and the energy realized was 972 foot-tons. With the weight of shot trebled—that is, increased to 90 pounds, the total velocity fell to 1,370 foot-seconds and the energy increased to 1,178 foot-tons.

Further increases in the weight of the shot to 120 pounds, 150 pounds, and 360 pounds gave energies practically identical, viz., 1,196, 1,192, and 1,192 foot-tons, thus entirely confirming Robins's view.

I think that I may venture to say that the question of the pressures developed by fired gunpowder was set at rest by the experiments made by myself and described in a paper by Sir F. Abel and myself in the transactions of the Royal Society. In these experiments I succeeded in determining for the three powders of the English service, pebble, rifle large grain, and fine grain, the tension of the exploded gas at all densities up to unity, and in altogether retaining the whole of the products of explosion, even of charges of several pounds, which filled entirely or nearly so the chambers of the explosion vessels. The result of my experiments gave for a density of unity a pressure of about 6,500 atmospheres. The temperatures of explosion of the different gunpowders varied considerably, but were generally between 2,000 deg. C. and 2,230 deg. C.

I have never been able to understand why the considerable proportion of sulphur was so long retained as a component of gunpowder. In the English service, shortly before the adoption of modern propellants, it was almost entirely dispensed with in cocoa powder, and with a view of studying the question I had in 1883 four experimental powders made; in two of these powders sulphur was dispensed with, or nearly so; in the third, the amount of sulphur was halved; and in the fourth, the percentage was increased. The powder without sulphur had its potential energy increased by about 13 per cent, while that with increased sulphur was decreased by 9 per cent.

The early methods for testing the potential energy and uniformity of gunpowder were very rude, and permitted in this country powders to be passed into the service which showed great variations in potential energy.

My attention was called to this point in 1860, when, being then an associate member of the Ordnance Select Committee and carrying out experiments for that body, I found that the variation in the energy developed by new powders of different makes occasionally amounted to 25 per cent.

The variation admitted at the present day in passing propellants is about 2.8 per cent.

The early improvements in the old gunpowder were due to the labors of Major Rodman, U. S. A., who seems to have been the first to appreciate the importance of a suitable and uniform density of the powder, but also by the introduction of prismatic powder showed that it was possible considerably to reduce the very high and variable pressures which were common in the old guns, pressures which would not be permitted in the much stronger guns of the present day. He was also the inventor of a most ingenious instrument for determining the pressure developed by the explosion of the charge in the chambers or bores of guns, and Major Rodman's work was continued in this country by the labors of the first explosive committee, who not only determined with great accuracy the pressures of the propellants and the velocity of the projectiles at all points of the bore, but also increased the velocity by over 220 foot-seconds, thus increasing the energy developed by about 33 per cent, while the maximum pressure was reduced by about the same percentage—a matter of very great importance in the case of all, but especially of breech-loading guns.

But I fear I have detained you too long with the old gunpowders, and perhaps the easiest way of showing the striking difference between the old gunpowders and some of the modern propellants is to give you two tables exhibiting, first, the volume of gas generated by the explosion; second, the units of heat generated; and third, the product of the units of heat and volumes of gas, which represents approximately the comparative potential energy of the explosives.

I say "approximately," because both the units of heat and the quantity of gas vary considerably, dependent on the pressure under which the propellant is exploded, but I have in the tables taken the transformation approximately at the pressures at which the propellants are generally used in guns.

For cordite, the first modern propellant adopted in

* Read before the Institution of Engineers and Shipbuilders in Scotland and the North-East Coast Institution of Engineers and Shipbuilders.

England, we were indebted to the labors of the late Sir F. Abel and Sir James Dewar, and the value of the propellant is sufficiently shown by the fact that with the same maximum pressure artillerists have been able to more than double the energy of the projectile.

It will be observed that the figures I give as representing the comparative energies of the old propellants vary from 200,438 to 179,478, while the similar figures for the modern explosives vary from 1,090,873 to 851,212, or more than four times as great, and the diagram I also show exhibits the comparative pressures developed up to the density of 5, thus at the density of 5 the pressure of gunpowder is about 1,700 atmospheres—amide powder 3,500 atmospheres—while the modern explosives at the same density lie between pressures of 8,600 and 7,200 atmospheres.

Older Propellants.

	Pebble.	R. L. G.	F. G.	Mining Powder.	Spanish Powder.
Volumes of gas......	278	274	263	360	234
Units of heat	721	726	738	517	767
Comparative energy..	200,438	198,924	194,094	186,120	179,478

Modern Propellants.

	Cordite Mark I.	Italian Ballistite.	M. D. Cordite.	Norwegian 167	Nitro-cellulose.	Norwegian 165
Volumes of gas......	875.5	810.5	913.5	899.9	934.0	909.9
Units of heat........	1,246.0	1,305.0	1,030.0	1,005.5	924.0	935.5
Comparative energy.	1,090,873	1,057,703	940,905	904,850	863,016	851,212

Turning now to the total volumes of gas generated and the units of heat developed by the explosion, I find in the various explosions I have examined the same general rules hold. With the increase of density the volumes of gas decrease and the units of heat increase.

Thus, taking one or two illustrations, with an Italian ballistite at the density of 0.05, the total volume of gas per gramme was 824 cubic centimeters, while at the density of 0.5 it was 780 cubic centimeters; with M. D., cordite the corresponding figures at these densities were 955 cubic centimeters and 789 cubic centimeters; and with a Norwegian ballistite 959 cubic centimeters and 780 cubic centimeters, showing reductions in volume respectively for the three explosives of 44, 166, and 179 cubic centimeters per gramme.

The corresponding units of heat at the same densities are—for the Italian ballistite 1,228 and 1,264, for the M. D. cordite 965 and 1,178, and for the Norwegian ballistite 860 and 1,092, or increments respectively of 36, 213, and 232 units, and I draw attention to the remarkable difference in the increments of heat in these three explosives.

The pressures developed by these same explosives were at the density of 0.05 respectively 457, 457, and 389 atmospheres, while at the density of 0.5 the pressures rose to 7,956, 7,545, and 8,536 atmospheres, or from about 17 to 22 times as great.

It is hardly necessary to say that the last-named pressures are greatly above those which are permissible in guns, but they are interesting as showing how greatly the pressure and temperature of explosion increase with the increase of density of charge.

Thus, taking for the three explosives I have selected, the density of 0.25 as representing approximately the maximum density permissible in guns, it is found that the pressure for the Italian ballistite is 3,148, for the M. D. cordite 3,193, and for the Norwegian ballistite 2,896 atmospheres, while at the double density of 0.5 these pressures become respectively 7,956, 7,545, and 8,536 atmospheres, the pressure last named being approximately three times as great as that at the density of 0.25.

Now, I have pointed out that with the increase of density there is in all cases a decrease, in most cases a considerable decrease in the volume of gas, and as the pressures developed increase much more rapidly than the density, it is obvious that with increase of density there must be a very considerable increase of temperature.

At a density of 0.5 I place the temperatures of the high explosives I have examined as varying between 4,000 deg. and 5,000 deg. C. I need not say that at less densities they are very much lower.

I have mentioned that the percentages of the several gases generated by the explosion vary greatly, dependent upon the pressure under which the explosion takes place, and I shall exhibit to you three diagrams, in two of which there are, with increase of density, large increases in volume, and in the third a considerable decrease.

I shall take first carbonic acid, and it will be observed that in all cases the differences in volume between the low and high densities are large. In M. D. cordite, for example, the percentage varies from 14.8 to 32.4, and it will be observed that as the densities increase the differences in the percentage greatly diminish.

Thus, at a density of 0.05 there is a difference between the several explosions of 13 per cent, while at 0.5 density this difference is reduced to 3 per cent.

At the density of 0.05 the percentage of marsh gas (CH_4) in all cases is very small, under a half per cent, but the percentage increases rapidly, and in this case, instead of the percentage approximating at the higher densities, there is very considerable divergence.

With regard to the percentage volume of hydrogen, it will be observed that at the lowest density there is a considerable difference, the percentages varying from 8 per cent to over 20 per cent; the whole of the percentages slightly rise with increase of density and then rapidly fall, finally closely approximating, the difference at 0.5 density being only about 1½ per cent.

But I must not fatigue you with these somewhat dry figures, and I will only draw attention to one other point.

The whole of the new propellants develop on explosion a very much higher temperature than did the old gunpowders, and the introduction of armored vessels has necessitated the employment of guns 15 or 16 times heavier than the guns in use fifty years ago, and capable of giving to their projectiles energies nearly fifty times as great.

Now, as regards the serious question of erosion, in the case of the very large guns it is important to remember that while the surface of the bore subject to the more violent erosion increases approximately as the caliber or a little more, the charge of the propellant required to give to similar projectiles the same maximum velocity increases as the cube of the caliber; and, consequently, unless special arrangements as to the projectile are made, or other means adopted, the life of the largest guns before re-lining must be short when compared with that of smaller guns.

It, therefore, becomes a matter of great importance that attention should be given to the best method of reducing erosion when very large charges are used, either by lowering the temperature of explosion of the propellant, or possibly by introducing with the charge some cooling agent.

As regards the first of these points some very considerable advance has been made, as will be seen by some specimens of the erosive action of a few different propellants I have placed upon the table, but I venture to think that the question of erosion has, at least in this country, hardly received sufficient attention, and that, in some respects, mistaken notions as to the amount of erosion with reduced charges are entertained.

For instance, it has been stated that in a gun the erosion due to 4 three-quarter charges and 16 half charges is in each case equivalent to that due to one full charge; and for several explosives I have tested, in the manner I have for many years adopted, the absolute capacity for erosion of several propellants, and as the temperature of explosion varies with the density, I selected the density at which propellants are generally fired in guns. The propellants varied very considerably in their capacity for erosion, but all gave the same result, viz., that the erosion due to one three-quarter charge was less than that of a full charge, but that two three-quarter charges gave more erosion than one full charge, while two half charges gave less, but three half charges gave more erosion than one full charge; or, in other words, that the erosion was a little less than that due to the comparative weight of the charges.

SUBMARINES AND LIFE-SAVING DEVICES.

Nearly two years ago we had an opportunity of witnessing tests of the safety helmets at the works of the makers, at which time the appliances had been adopted for use by the Admiralty. The apparatus is so simple, and can be constructed so rapidly, that there does not seem any valid reason why an ample supply could not have been obtained to equip every submarine on commissioning. As regards the air traps, which must be constructed within the hold of the boat for use in conjunction with the safety helmets, the fitment of the screens can be effected without any delay or difficulty in the case of boats under construction, and is only a matter of the detention of the older submarines in dockyard hands for a few days or weeks.

The helmet appliance consists of a short tunic of water-proof material, to which is united a helmet containing cartridges of a certain chemical substance, which, in the presence of water vapor of the breath, gives off pure oxygen, and takes up the carbon dioxide of the expired air. In this respect the apparatus is similar to certain forms of self-contained smoke helmets for use in mines. As adapted for submarines the helmet and jacket complete weighs only 16 pounds. For use in conjunction with the helmet a submarine is fitted with a pair of steel curtains or screens, one on either side of the hull, pendant from the shell plating of the main compartment. These screens are closed at either end, and extend to within about 3 feet 6 inches of the deck of the boat, thus forming air traps in the event of the hull becoming flooded with water. Within these traps, which are open at the bottom, are suspended helmets for each one of the crew; each helmet is arranged with the dress tucked up inside it, and if by any mishap the hold is flooded with members of the crew below, or the air becomes charged with chlorine gas, those in danger can quickly get under the steel screens and stand up with their heads and shoulders in the air trap and out of reach of the water. The putting on of the helmet and jacket is a matter of a few moments, the appliance being dropped over the head and the arms inserted. The tap admitting air to the oxygen-producing cartridge is then opened, and a supply of oxygen sufficient for half an hour or more is insured.

The next step to gain safety no doubt contains some elements of excitement and danger, but any risks are preferable to the almost certainty of a horrible death which awaits those unfortunate enough to be in the hold of a submarine at the time of a serious disaster. If the accident has resulted in the formation of poisonous fumes of chlorine gas, the apparatus enables the wearers to escape through the conning towers with safety, or, perhaps, to rectify defects in the machinery. On the other hand, if a collision results in the sinking of the boat with the conning tower open, the unfortunate man below rushes to the temporary shelter of the trap, and, having donned the helmet, gets under the screen, and finds his way as best he can to the open hatchway, and quickly floats to the surface. In comparatively shallow water, as, for instance, up to 20 fathoms, the ascent to the surface, when once the man is clear of the boat, presents no difficulties, and the dress itself acts as a lifebuoy which will enable the wearer to float without difficulty so long as the supply of oxygen holds out. In deep water the physiological dangers attending a too rapid ascent have to be faced. Even when the conning tower's hatch happens to be closed, it can be opened from within the sunken boat as soon as the hold is flooded to a sufficient degree to equalize the hydrostatic pressure within and without. There is another set of conditions in which the helmet may be used with good prospects of success. In the case of a boat becoming disabled when submerged and refusing to rise to the surface, the crew are able to don their helmets, and then deliberately to flood the compartment, when the hatchway can be opened, and the way of escape to the surface provided.

The trials to which these safety appliances have been subjected have undoubtedly shown that they at least offer a fair chance of safety to the men who risk their lives in the most dangerous form of warship in common use. It is stated that on one occasion when a submarine was accidentally sunk in a basin two men escaped by means of the air trap, without any helmet, but this was in shallow water, and the fore-hatch was open.—Engineer.

SPEED OF INDIAN RAILWAY TRAINS.

Some interesting information with regard to the speed of railway trains in India is given by the Indian Railway Gazette. It seems that owing to its superior permanent way, the East Indian Railway attains the greatest average speed over a long distance, the journey from Calcutta to Jubbulpore being accomplished at an average speed of 34.663 miles an hour, while the Bengal-Nagpur travels from Calcutta to Nagpur at an average of 29.80 per hour. The fastest train in India is the weekly Special Postal over the Great Indian Peninsular and the East Indian lines, which covers the breadth of India at an average of 35.5 miles per hour, including all stoppages. As the distance is 1,349 miles, this must certainly be considered fast traveling —for India—although to people accustomed to the express trains from London to Edinburgh and London to Bristol or Plymouth, whose average works out to well over 50 miles per hour, the Indian timing may seem slow. But in view of the huge distances covered in India and the enormous agricultural population for whose benefit certain trains must daily stop at numerous small stations, the speed obtained is undoubtedly good. The number of Indian railway passengers has greatly increased in recent years, and with advance in education and the greater development of western ideas among the peoples of India this increase will no doubt continue. The populations of the big cities are also growing rapidly, and these facts ought to influence railways in putting on faster express trains.

A NOVEL SALVAGING OPERATION.

HOW THE "NETHERTON" WAS TAKEN HOME.

BY THE ENGLISH CORRESPONDENT OF THE SCIENTIFIC AMERICAN.

SOME two years ago the steamship "Netherton" lay in the roads of Singapore. Her forward hold was laden with a heavy consignment of benzine, which suddenly blew up and precipitated a fire. With much difficulty the outbreak was extinguished, but under the combined agency of explosion and fire the vessel had suffered extreme damage. The force of the explosion was tremendous, and the effect curious. The shell plating on either side of the ship forward of the engine room to the bows was bodily crushed in above the waterline, and amidships the buckling was so severe that the plating lay over where the deck had been, and offered a flat surface upon which one could stand and survey the boat from stem to stern. Though the plating was torn here and there and badly twisted, it was not punctured, but was pulled inward bodily on either side, as the accompanying photographs show.

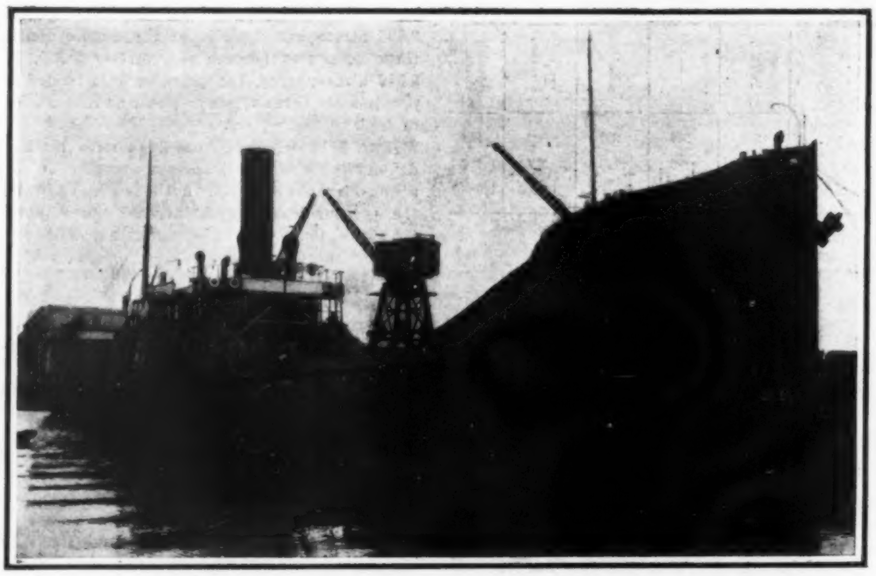
Within, however, the vessel was nothing more than a tumbled mass of twisted and broken iron, the woodwork having been burned away by the fire, while all upper works had tumbled into the hold. When the underwriters' engineers inspected the boat, they reported that she was merely a mass of scrap iron. To patch her up and get her away would have entailed drydocking. At Singapore it was found that this would be such an expensive matter as to render the operation financially impossible. As no scheme could be devised for effecting repairs without drydocking, the vessel was abandoned as a total loss. The boat could not be left where she was anchored, for which reason the wreck was put up for sale. At first there were no bidders, so precarious seemed the problem of getting it away.

At last the English firm of W. H. Loveridge & Co. at West Hartlepool bought the wreck and dispatched Mr. W. J. Russell, a well-known marine surveyor, who has had considerable experience of such work in the East, to Singapore to see if he could not temporarily repair her where she lay so as to bring her back to England.

When he arrived on the scene, wind and rain had completed the devastation wrought by explosion and fire. The intermediate decks had been burned or blown away and rain water had flooded the holds to a depth of two feet. Before a comprehensive repairing scheme could be drawn up, this water had first to be pumped out. A pulsometer pump was rigged up, and a tug brought alongside to supply steam for its operation. After the hold was clear, the surveyor drew up his specifications of temporary repairs to render the vessel seaworthy, and submitted them to the Straits Settlements government authorities. With but slight modifications the plans were approved, and the repairs were intrusted to Messrs. Riley, Hargreaves & Co., the well-known engineers of Singapore.

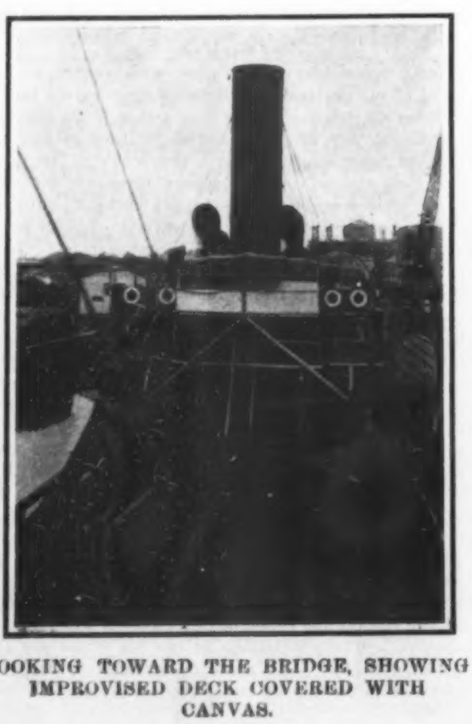
The tangled iron debris was removed from the holds to permit of the laying of an improvised deck from the forecastle to amidships. This was then covered with canvas and rendered fairly water-tight. The greatest obstacle, however, was to strengthen the hull over the stretch where the shell plating had been forced inward. This was at last ingeniously overcome by fixing a heavy longitudinal steel girder right over the damaged section, as shown in the photograph, the girder being stiffened by vertical struts, plates, and angles, disposed at frequent intervals.

Examination of the machinery showed that the damage by the explosion had been fairly localized to the forward hold, only the smokebox doors and a few other trifles being torn from the boilers, which themselves were apparently sound and in good condition. They were overhauled and thoroughly tested first, cold, at 200 pounds, and afterward with steam at 160 pounds. In the engine room itself everything was found in fair condition. The copper in the form of pipes and fittings, which had been plundered by the natives, had to be renewed, but as copper is so prohibitive in price in Singapore, iron piping was freely used, copper being reserved only for the main steam piping, some expansion bends, steam steering gear, and the like. The ship's pumps were thoroughly overhauled, and an independent 6-inch centrifugal pump rigged up in the forward hold to deal with any water that might possibly be shipped during the homeward voyage. The underwater part of the hull was cleared by Malay divers as best they could under the adverse circumstances. Subsequent examination showed that scraping had been completed in a very praiseworthy manner. From first to last the repairs occupied thirty days, which bearing in mind the delicate and difficult character of the work and the whole of its execution *in situ*, was a notable achievement.



THE "NETHERTON" AT SINGAPORE, SHOWING DAMAGE WROUGHT BY EXPLOSION. NOTE THE STIFFENING GIRDER ON SIDE.

When all was finished, a trial trip was carried out to test the repairing work, and ascertain whether it was safe to undertake the long journey of several thousand miles home. On this trial trip she made $7\frac{1}{2}$ knots per hour. Mr. Russell decided to bring her to England under her own steam. The curious-looking wreck thus set out, and after a protracted, tedious journey safely reached West Hartlepool. This successful salvage feat after a vessel had been abandoned as hopeless, and its travel over such a long distance after being patched up, ranks as an interesting achievement.



LOOKING TOWARD THE BRIDGE, SHOWING IMPROVISED DECK COVERED WITH CANVAS.

SIDE SHELL PLATING BENT INWARD BY EXPLOSION.

Longitudinal side girder introduced to strengthen ship for voyage home.

AMOUNT OF MOISTURE IN FOGS.

OBSERVATIONS were made on the Sonnblick in July, 1908, by A. Wagner on the percentage humidity of fogs and on the amount of moisture contained in each cubic meter. I. For the former measurement four hair hygrometers of different patterns were used. The instruments were standardized by placing them (1) in a cellar in which a constant humidity of 95 per cent was maintained; (2) in a steam chamber in which the air was saturated. The humidity in the cellar was determined with an Alluard dew-point hygrometer. The humidity, as measured by these hygrometers, exceeded 100 per cent on all occasions of fog except those on which the sun's disk could be seen. If we omit these cases of light fog, the mean humidity during fog was 102.4 per cent. The seven cases omitted give a mean of 90.5 per cent. The question whether this supersaturation is real is then discussed, but no very definite result is arrived at. It is not caused by water-drops adhering to the apparatus and influencing the readings mechanically. The vapor pressure is greater over curved surfaces than over flat ones, but the amount of supersaturation is too great to be explained from the curvature of the drops. II. The amount of water per cubic meter was determined by drawing air into a wide-necked bottle of 13.56 liters capacity and then passing it through H_2SO_4 and $CaCl_2$ and determining the moisture chemically. From the known temperature and pressure the amount of water-vapor present can be calculated, and subtraction gives the amount of liquid water per cubic meter. The amount varied between 0.12 gramme and 4.84 grammes, the mean of 22 experiments giving 2 grammes. The weight of water present in the liquid state was always smaller than that present as vapor. The distance at which objects could be seen was very nearly proportional inversely to the amount of liquid water present per cubic meter. No definite relation was found between the visibility and the size of the drops as determined by optical methods.—Akad. Wiss. Wien, Sitz. Ber.

THE AERIAL PROPELLER.

ITS FORM AND CONSTRUCTION.

BY LUCIEN FOURNIER.

Some questions are much easier to ask than to answer. The aerial propeller belongs to the category of scientific apparatus which must be defined with caution, because it seems impossible to make a perfectly clear definition without using technical language. Usually, the definition is passed over rapidly, while volumes are written on the theory, although the formulæ can only be determined by experiment. I shall endeavor to describe the aerial propeller in language intelligible to my readers. The only definition which can be given is the following: A screw propeller is an organ which, by pressing upon a fluid, propels the vessel to which it is attached. This definition is incomplete because the screw is not the only form of propeller, because it assumes different forms in different fluids, because it may either pull or push the vessel, and, above all, because we possess only very vague knowledge concerning its efficiency. Nevertheless, we shall accept this definition, which we shall complete by the use of analogies as we proceed.

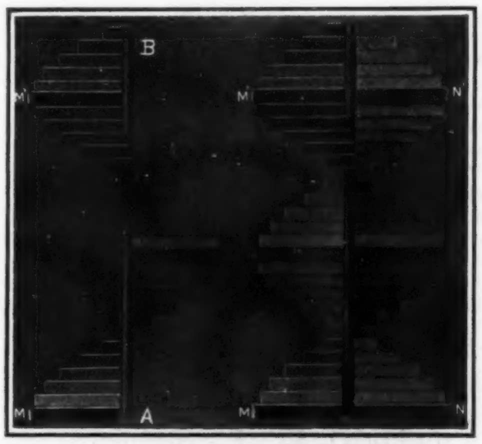


Fig. 1.—SINGLE AND DOUBLE WINDING STAIRS (VERTICAL SECTION.)

Fig. 1 represents a vertical section of a winding stair in which all the steps radiate from a central pillar. Let us suppose that one of these steps, *M*, moves along a helical groove cut in the pillar *A B*. Each of its points will describe a helix and, when the step has accomplished an entire revolution, it will be in a position, *M'*, parallel to its original position, and at a certain distance vertically above it. This distance is equal to what is called the pitch of the screw thread which has guided the movement. Let us now imagine two stairs winding around the same pillar, as shown in the right-hand figure, and let us consider two steps, *M* and *N*, diametrically opposite each other. If each of these steps is capable of movement along a helical furrow, we shall obtain, in each case, a motion identical with the motion already described. The pitch is supposed to be the same for both, hence the resulting figure will assume the appearance of a screw formed of horizontal plane elements, corresponding to an infinite number of steps.

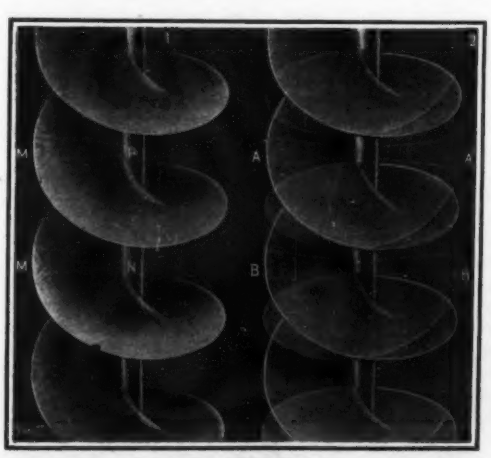


Fig. 2.—SINGLE AND DOUBLE ARCHIMEDES SCREWS (VERTICAL SECTION.)

If the pillar were horizontal, what would occur? A precisely similar result, even if the two steps were immersed in a fluid. If the steps are attached rigidly to the pillar and the latter is rotated, the pillar will not exert any longitudinal thrust, because the steps are plane surfaces perpendicular to its axis. The power of the motor would be entirely consumed in overcoming the skin friction between the air and the steps. Hence, this does not form a propeller; but if each step is twisted, so as to be inclined to the axis, it will exert an oblique pressure upon the air in its revolution. In a fluid of little density, like air, this pressure is not very large in comparison with the skin friction. The ideal aerial propeller is one which can move through the air without friction. In this case, the entire power of the motor would be transformed into useful work, and a maximum thrust would be transmitted to the propeller shaft. The actual aerial propeller is of better construction than the one just described. Its blades are not plane, but are curved in a manner skillfully designed to produce a maximum efficiency. In order to give an idea of this curvature, and its possible variations, let us regard a vertical section of an Archimedes screw, an apparatus which is used for raising pulverized substances (Fig. 2). Let us consider the small slice, *M*, as we previously considered a single step of the winding stair. This element of the Archimedes screw is not a plane surface, but has a curvature which depends upon the pitch of the screw and its radius. Two such elements attached, opposite each other, to the same shaft represent a two-bladed propeller of definite curvature.

It is evident that this curvature cannot be a matter of indifference, for it is intimately connected with the distance *A B* between two points on the same generatrix of the screw; that is to say, upon the pitch of the screw. In short, we shall obtain a figure similar to that which would have been formed by twisting in opposite directions the two steps of the preceding illustration. The form of a propeller blade can be imitated by holding one end of a rectangular strip of paper and turning the other end about an axis parallel to the length of the strip. Wilbur Wright forms such a surface in deforming his aeroplanes in steering. If, at the moment of this maneuver, the aeroplane were attached to a fixed vertical axis, it would revolve about this axis like an ordinary propeller.

Fig. 3.—CONSTRUCTION OF A CHAUVIÈRE PROPELLER WITH FOUR BLADES.

We come now to the behavior of the propeller in the air. The solution of this problem is due to Col. Renard, who has conceived the idea of giving to the blades such a direction that the effort exerted upon them is parallel to their length. In Fig. 6 *X X* represents the shaft of a propeller, *S* an element of the blade, and *S O* the arm, or middle line of the blade. The curved arrow shows the direction of rotation. Three forces act upon the element *S*, the axial thrust *A*; the resistance to rotation, *B*, which, in well-constructed propellers, is about one-fourth or one-fifth of *A*, and the radial force *C*. The stress upon the arm, which tends to bend it, is due wholly to the thrust *A*. By inclining the arm to *O S*, in the plane *O S A*, so that the arm assumes the direction of the resultant of the forces *A* and *C*, the stress upon it will be made practically longitudinal, for the bending effect of the force *B* is very small and may be neglected. This construction has been adopted in the propeller of the dirigible balloon "Ville de Paris," the blades of which assume automatically during the rotation the direction of the three forces *A*, *B*, *C*. This inclination, once determined by experiment, can always be reproduced by means of a graduated arc, *J*.

The construction of the aerial propeller is the more delicate, because it depends to a large extent upon the peculiarities of the vessel to which it is to be attached. I have had the privilege of witnessing the manufacture of wooden propellers in two of the principal French aeroplane factories, those of the Astra Society and of M. Chauvière. The methods employed in all establishments are the same, yet a Chauvière propeller is very different from a Wright propeller. The latter is made of American spruce and is of very light construction. The extremities of the blades are covered with canvas which is varnished with the rest, for the purpose of increasing the rigidity of the outer ends, which are very thin. The Wright propeller is built up of three planks arranged as shown in Fig. 4, so that they overlap like the sticks of a fan, to an extent which diminishes as the distance from the axis increases. The superfluous parts of the wood represented by the darker and triangular areas of the upper diagrams in Fig. 4, are then cut away, and the curvature is tested at every point by patterns. These operations are illustrated in Figs. 3 and 5. Chauvière propellers are made of walnut, and include six or seven overlapping planks. The finished propeller contains only about 8½ per cent of the wood of the original planks.

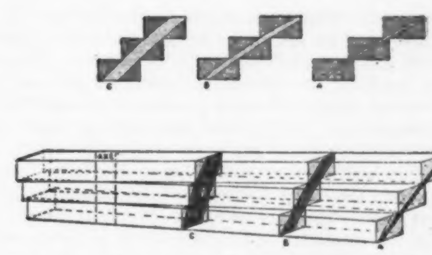


Fig. 4.—DIAGRAM AND SECTIONS OF PROPELLER BLADE FORMED OF THREE OVERLAPPING PLANKS.

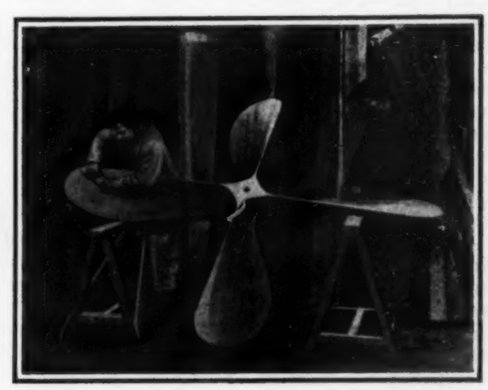


Fig. 5.—POLISHING A PROPELLER AFTER SHAPING.

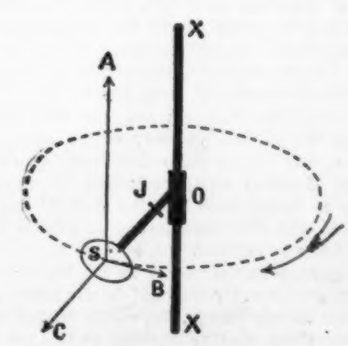


Fig. 6.—DIAGRAM OF FORCES ACTING ON A PROPELLER BLADE.

It should be added that constructors show little disposition to furnish exact details of their methods. Their industry is so new that they take jealous care in guarding their secrets, for which reticence they cannot be blamed. Yet the methods can be inferred from our knowledge of the problem. In the case of

three beams assembled fan-wise (Fig. 4) let us consider three sections, *A*, *B*, and *C*, parallel to the axis and at varying distances from it. The general directions of these sections will be more or less inclined to the axis according to their distance from it. The study of these three sections will explain both the progressive variation in slope and curvature from the axis to the periphery, and the corresponding variation in the thickness of the blade.

Propellers are also made of metal. In these the blades are soldered or riveted to the arms, which are steel tubes riveted to the nave. The blades are shaped by hammering upon a form. In some cases they are cast, or twisted into shape, but this construction is inferior to the preceding.—La Nature.

STUDIES OF ELECTRICITY AND MATTER.*

A RESUMÉ OF RECENT INVESTIGATION.

BY SIR J. J. THOMSON.

Concluded from Supplement No. 1757, page 155.

I attempted several years ago to find the ratio of mass to weight for radium by swinging a little pendulum, the bob of which was made of radium. I had only a small quantity of radium, and was not, therefore, able to attain any great accuracy. I found that the difference, if any, in the ratio of the mass to weight between radium and other substances was not more than one part in 2,000. Lately we have been using at the Cavendish Laboratory a pendulum whose bob was filled with uranium oxide. We have got good reasons for supposing that uranium is a parent of radium, so that the great potential energy and large ethereal mass possessed by the radium will be also in the uranium; the experiments are not yet completed. It is, perhaps, expecting almost too much to hope that the radio-active substances may add to the great services they have already done to science by furnishing the first case in which there is some differentiation in the action of gravity.

The mass of ether bound by any system is such that if it were to move with the velocity of light its kinetic energy would be equal to the potential energy of the system. This result suggests a new view of the nature of potential energy. Potential energy is usually regarded as essentially different from kinetic energy. Potential energy depends on the configuration of the system, and can be calculated from it when we have the requisite data; kinetic energy, on the other hand, depends upon the velocity of the system. According to the principle of the conservation of energy the one form can be converted into the other at a fixed rate of exchange, so that when one unit of one kind disappears a unit of the other simultaneously appears.

Now in many cases this rule is all that we require to calculate the behavior of the system, and the conception of potential energy is of the utmost value in making the knowledge derived from experiment and observation available for mathematical calculation. It must, however, I think, be admitted that from the purely philosophical point of view it is open to serious objection. It violates, for example, the principle of continuity. When a thing changes from a state A to a different state B, the principle of continuity requires that it must pass through a number of states intermediate between A and B, so that the transition is made gradually, and not abruptly. Now, when kinetic energy changes into potential, although there is no discontinuity in the quantity of the energy, there is in its quality, for we do not recognize any kind of energy intermediate between that due to the motion and that due to the position of the system, and some portions of energy are supposed to change *per saltum* from the kinetic to the potential form. In the case of the transition of kinetic energy into heat energy in a gas, the discontinuity has disappeared with a fuller knowledge of what the heat energy in a gas is due to. When we were ignorant of the nature of this energy, the transition from kinetic into thermal energy seemed discontinuous; but now we know that this energy is the kinetic energy of the molecules of which the gas is composed, so that there is no change in the type of energy when the kinetic energy of visible motion is transformed into the thermal energy of a gas—it is just the transference of kinetic energy from one body to another.

If we regard potential energy as the kinetic energy of portions of the ether attached to the system, then all energy is kinetic energy, due to the motion of matter or of portions of ether attached to the matter. I showed, many years ago, in my "Applications of Dynamics to Physics and Chemistry," that we could imitate the effects of the potential energy of a system by means of the kinetic energy of invisible systems connected in an appropriate manner with the main system, and that the potential energy of the visible universe may in reality be the kinetic energy of an invisible one connected up with it. We naturally suppose that this invisible universe is the luminiferous ether, that portions of the ether in rapid motion are connected with the visible systems, and that their kinetic energy is the potential energy of the systems.

We may thus regard the ether as a bank in which we may deposit energy and withdraw it at our convenience. The mass of the ether attached to the system will change as the potential energy changes, and thus the mass of a system whose potential energy is changing cannot be constant; the fluctuations in mass under ordinary conditions are, however, so small that they cannot be detected by any means at present at our disposal. Inasmuch as the various forms of potential energy are continually being changed into heat energy, which is the kinetic energy of the molecules of matter, there is a constant tendency for the mass of a system such as the earth or the sun to diminish, and thus as time goes on for the mass of ether gripped by the material universe to become smaller and smaller; the rate at which it would diminish would, however, get slower as time went on, and there is no reason to think that it would ever get below a very large value.

Radiation of light and heat from an incandescent body like the sun involves a constant loss of mass by the body. Each unit of energy radiated carries off its quota of mass, but as the mass ejected from the sun per year is only one part in 20 billionths (1 in 2×10^{13}) of the mass of the sun, and as this diminution in mass is not necessarily accompanied by any decrease in its gravitational attraction, we cannot expect to be able to get any evidence of this effect.

As our knowledge of the properties of light has progressed, we have been driven to recognize that the ether, when transmitting light, possesses properties which, before the introduction of the electro-magnetic theory, would have been thought to be peculiar to an emission theory of light and to be fatal to the theory that light consists of undulations.

Take, for example, the pressure exerted by light. This would follow as a matter of course if we supposed light to be small particles moving with great velocities, for these, if they struck against a body, would manifestly tend to push it forward, while on the undulatory theory there seemed no reason why any effect of this kind should take place.

Indeed, in 1792, this very point was regarded as a test between the theories, and Bennet made experiments to see whether or not he could find any traces of this pressure. We know now that the pressure is there, and if Bennet's instrument had been more sensitive he must have observed it. It is perhaps fortunate that Bennet had not at his command more delicate apparatus. Had he discovered the pressure of light, it would have shaken confidence in the undulatory theory and checked that magnificent work at the beginning of the last century which so greatly increased our knowledge of optics.

As another example, take the question of the distribution of energy in a wave of light. On the emission theory the energy in the light is the kinetic energy of the light particles. Thus the energy of light is made up of distinct units, the unit being the energy of one of the particles.

The idea that the energy has a structure of this kind has lately received a good deal of support. Planck, in a very remarkable series of investigations on the thermodynamics of radiation, pointed out that the expressions for the energy and entropy of radiant energy were of such a form as to suggest that the energy of radiation, like that of a gas on the molecular theory, was made up of distinct units, the magnitude of the unit depending on the color of the light; and on this assumption he was able to calculate the value of the unit, and from this deduce incidentally the value of Avogadro's constant—the number of molecules in a cubic centimeter of gas at standard temperature and pressure.

This result is most interesting and important because if it were a legitimate deduction from the Second Law of Thermodynamics, it would appear that only a particular type of mechanism for the vibrators which give out light and the absorbers which absorb it could be in accordance with that law.

If this were so, then, regarding the universe as a collection of machines all obeying the laws of dynamics, the Second Law of Thermodynamics would only be true for a particular kind of machine.

There seems, however, grave objection to this view, which I may illustrate by the case of the First Law of Thermodynamics, the principle of the Conservation of Energy. This must be true whatever be the nature of the machines which make up the universe, provided they obey the laws of dynamics, any application of the principle of the Conservation of Energy could not discriminate between one type of machine and another.

Now, the Second Law of Thermodynamics, though not a dynamical principle in as strict a sense as the law of the Conservation of Energy, is one that we should expect to hold for a collection of a large number of machines of any type, provided that we could not directly affect the individual machines, but could only observe the average effects produced by an enormous number of them. On this view, the Second Law, as well as the First, should be incapable of saying that the machines were of any particular type: so that investigations founded on thermodynamics, though the expressions they lead to may suggest—cannot, I think, be regarded as proving—the unit structure of light energy.

It would seem as if in the application of thermodynamics to radiation some additional assumption has been implicitly introduced, for these applications lead to definite relations between the energy of the light of any particular wave length and the temperature of the luminous body.

Now a possible way of accounting for the light emitted by hot bodies is to suppose that it arises from the collisions of corpuscles with the molecules of the hot body, but it is only for one particular law of force between the corpuscles and the molecules that the distribution of energy would be the same as that deduced by the Second Law of Thermodynamics, so that in this case, as in the other, the results obtained by the application of thermodynamics to radiation would require us to suppose that the Second Law of Thermodynamics is only true for radiation when the radiation is produced by mechanism of a special type.

Quite apart, however, from considerations of thermodynamics, we should expect that the light from a luminous source should in many cases consist of parcels, possessing, at any rate to begin with, a definite amount of energy. Consider, for example, the case of a gas like sodium vapor, emitting light of a definite wave length; we may imagine that this light, consisting of electrical waves, is emitted by systems resembling Leyden jars. The energy originally possessed by such a system will be the electrostatic energy of the charged jar. When the vibrations are started, this energy will be radiated away into space, the radiation forming a complex system, containing, if the jar has no electrical resistance, the energy stored up in the jar.

The amount of this energy will depend on the size of the jar and the quantity of electricity with which it is charged. With regard to the charge, we must remember that we are dealing with systems formed out of single molecules, so that the charge will only consist of one or two natural units of electricity, or, at all events, some small multiple of that unit, while for geometrically similar Leyden jars the energy for a given charge will be proportional to the frequency of the vibration; thus the energy in the bundle of radiation will be proportional to the frequency of the vibration.

We may picture to ourselves the radiation as consisting of the lines of electric force which, before the vibrations were started, were held bound by the charges on the jar, and which, when the vibrations begin, are thrown into rhythmic undulations, liberated from the jar and travel through space with the velocity of light.

Now let us suppose that this system strikes against an uncharged condenser and gives it a charge of electricity, the charge on the plates of the condenser must be at least one unit of electricity, because fractions

* Abstracted from the Presidential address to the British Association for the Advancement of Science.

of this charge do not exist, and each unit charge will anchor a unit tube of force, which must come from the parcel of radiation falling upon it. Thus a tube in the incident light will be anchored by the condenser, and the parcel formed by this tube will be anchored and withdrawn as a whole from the pencil of light incident on the condenser. If the energy required to charge up the condenser with a unit of electricity is greater than the energy in the incident parcel, the tube will not be anchored and the light will pass over the condenser and escape from it. These principles that radiation is made up of units, and that it requires a unit possessing a definite amount of energy to excite radiation in a body on which it falls, perhaps receive their best illustration in the remarkable laws governing Secondary Röntgen radiation, recently discovered by Prof. Barkla. Prof. Barkla has found that each of the different chemical elements, when exposed to Röntgen rays, emits a definite type of secondary radiation whatever may have been the type of primary; thus lead emits one type, copper another, and so on; but these radiations are not excited at all if the primary radiation is of a softer type than the specific radiation emitted by the substance; thus the secondary radiation from lead being harder than that from copper, if copper is exposed to the secondary radiation from lead the copper will radiate, but lead will not radiate when exposed to copper. Thus, if we suppose that the energy in a unit of hard Röntgen rays is greater than that in one of soft, Barkla's results are strikingly analogous to those which would follow on the unit theory of light.

Though we have, I think, strong reasons for thinking that the energy in the light waves of definite wave length is done up into bundles, and that these bundles, when emitted, all possess the same amount of energy, I do not think there is any reason for supposing that in any casual specimen of light of this wave length, which may subsequent to its emission have been many times refracted or reflected, the bundles possess any definite amount of energy. For consider what must happen when a bundle is incident on a surface such as glass, when part of it is reflected and part transmitted. The bundle is divided into two portions, in each of which the energy is less than in the incident bundle, and since these portions diverge and may ultimately be many thousands of miles apart, it would seem meaningless to still regard them as forming one unit. Thus the energy in the bundles of light, after they have suffered partial reflection, will not be the same as in the bundles when they were emitted. The study of the dimensions of these bundles, for example the angle they subtend at the luminous source, is an interesting subject for investigation; experiments on interference between rays of light emerging in different directions from the luminous source would probably throw light on this point.

I now pass to a very brief consideration of one of the most important and interesting advances ever made in physics, and in which Canada, as the place of the labors of Profs. Rutherford and Soddy, has taken a conspicuous part. I mean the discovery and investigation of radio-activity. Radio-activity was brought to light by the Röntgen rays. One of the many remarkable properties of these rays is to excite phosphorescence in certain substances, including the salts of uranium, when they fall upon them. Since Röntgen rays produce phosphorescence, it occurred to Becquerel to try whether phosphorescence would produce Röntgen rays. He took some uranium salts which had been made to phosphoresce by exposure, not to Röntgen rays, but to sunlight, tested them, and found that they gave out rays possessing properties similar to Röntgen rays. Further investigation showed, however, that to get these rays it was not necessary to make the uranium phosphoresce, that the salts were just as active if they had been kept in the dark. It thus appeared that the property was due to the metal and not to the phosphorescence, and that uranium and its compounds possessed the power of giving out rays which, like Röntgen rays, affect a photographic plate, make certain minerals phosphoresce, and make gases through which they pass conductors of electricity.

Niepce de Saint-Victor had observed some years before this discovery that paper soaked in a solution of uranium nitrate affected a photographic plate, but the observation excited but little interest. The ground had not then been prepared, by the discovery of the Röntgen rays, for its reception, and it withered and was soon forgotten.

Shortly after Becquerel's discovery of uranium, Schmidt found that thorium possessed similar properties. Then Monsieur and Madame Curie, after a most difficult and laborious investigation, discovered two new substances, radium and polonium, possessing this property to an enormously greater extent than either thorium or uranium, and this was followed by the discovery of actinium by Debierne. Now the researches of Rutherford and others have led to the discovery of so many new radio-active substances that any attempts at christening seems to have been abandoned, and they are denoted, like policemen, by the letters of the alphabet.

Mr. Campbell has recently found that potassium, though far inferior in this respect to any of the substances I have named, emits an appreciable amount of radiation, the amount depending only on the quantity of potassium, and being the same whatever the source from which the potassium is obtained or whatever the elements with which it may be in combination.

The radiation emitted by these substances is of three types known as α, β, and γ rays. The α rays have been shown by Rutherford to be positively electrified atoms of helium, moving with speeds which reach up to about one-tenth of the velocity of light. The β rays are negatively electrified corpuscles, moving in some cases with very nearly the velocity of light itself, while the γ rays are unelectrified, and are analogous to the Röntgen rays.

The radio-activity of uranium was shown by Crookes to arise from something mixed with the uranium, and which differed sufficiently in properties from the uranium itself to enable it to be separated by chemical analysis. He took some uranium, and by chemical treatment separated it into two portions, one of which was radio-active and the other not.

Next, Becquerel found that if these two portions were kept for several months, the part which was not radio-active to begin with regained radio-activity, while the part which was radio-active to begin with had lost its radio-activity. These effects and many others receive a complete explanation by the theory of radio-active change which we owe to Rutherford and Soddy.

According to this theory, the radio-active elements are not permanent, but are gradually breaking up into elements of lower atomic weight; uranium, for example, is slowly breaking up, one of the products being radium, while radium breaks up into a radio-active gas called radium emanation, the emanation into another radio-active substance, and so on, and that the radiations are a kind of swan's song emitted by the atoms when they pass from one form to another; that, for example, it is when a radium atom breaks up and an atom of the emanation appears that the rays which constitute the radio-activity are produced.

Thus on this view the atoms of the radio-active elements are not immortal, they perish after a life whose average value ranges from thousands of millions of years in the case of uranium to a second or so in the case of the gaseous emanation from actinium.

When the atoms pass from one state to another they give out large stores of energy, thus their descendants do not inherit the whole of their wealth of stored-up energy, the estate becomes less and less wealthy with each generation; we find, in fact, that the politician, when he imposes death duties, is but imitating a process which has been going on for ages in the case of these radio-active substances.

Many points of interest arise when we consider the rate at which the atoms of radio-active substance disappear. Rutherford has shown that whatever be the age of these atoms, the percentage of atoms which disappear in one second is always the same; another way of putting it is that the expectation of life of an atom is independent of its age—that an atom of radium one thousand years old is just as likely to live for another thousand years as one just sprung into existence.

Now this would be the case if the death of the atom were due to something from outside which struck old and young indiscriminately; in a battle, for example, the chance of being shot is the same for old and young; so that we are inclined at first to look to something coming from outside as the cause why an atom of radium, for example, suddenly changes into an atom of the emanation. But here we are met with the difficulty that no changes in the external conditions that we have as yet been able to produce have had any effect on the life of the atom; as far as we know at present the life of a radium atom is the same at the temperature of a furnace as at that of liquid air—it is not altered by surrounding the radium by thick screens of lead or other dense materials to ward off radiation from outside, and what to my mind is especially significant, it is the same when the radium is in the most concentrated form, when its atoms are exposed to the vigorous bombardment from the rays given off by the neighboring atoms, as when it is in the most dilute solution, when the rays are absorbed by the water which separates one atom from another. This last result seems to me to make it somewhat improbable that we shall be able to split up the atoms of the non-radio-active elements by exposing them to the radiation from radium; if this radiation is unable to affect the unstable radio-active atoms, it is somewhat unlikely that it will be able to affect the much more stable non-radio-active elements.

The evidence we have at present is against a disturbance coming from outside breaking up of the radio-active atoms, and we must therefore look to some process of decay in the atom itself; but if this is the case, how are we to reconcile it with the fact that the expectation of life of an atom does not diminish as the atom gets older? We can do this if we suppose that the atoms when they are first produced have not all the same strength of constitution, that some are more robust than others, perhaps because they contain more intrinsic energy to begin with, and will therefore have a longer life. Now if when the atoms are first produced there are some which will live for one year, some for ten, some for a thousand, and so on; and if lives of all durations, from nothing to infinity, are present in such proportion that the number of atoms which will live longer than a certain number of years decrease in a constant proportion for each additional year of life, we can easily prove that the expectation of life of an atom will be the same whatever its age may be. On this view the different atoms of a radio-active substance are not, in all respects, identical.

The energy developed by radio-active substances is exceedingly large, one gramme of radium developing nearly as much energy as would be produced by burning a ton of coal. This energy is mainly in the α particles, the positively charged helium atoms which are emitted when the change in the atom takes place; if this energy were produced by electrical forces it would indicate that the helium atom had moved through a potential difference of about two million volts on its way out of the atom of radium. The source of this energy is a problem of the deepest interest; if it arises from the repulsion of similarly electrified systems exerting forces varying inversely as the square of the distance, then to get the requisite amount of energy the systems, if their charges were comparable with the charge on the α particle, could not when they start be further apart than the radius of a corpuscle, 10^{-13} centimeter. If we suppose that the particles do not acquire this energy at the explosion, but that before they are shot out of the radium atom they move in circles inside this atom with the speed with which they emerge, the forces required to prevent particles moving with this velocity from flying off at a tangent are so great that finite charges of electricity could only produce them at distances comparable with the radius of a corpuscle.

One method by which the requisite amount of energy could be obtained is suggested by the views to which I have already alluded—that in the atom we have electrified systems of very different types, one small, the other large; the radius of one type is comparable with 10^{-13} centimeter, that of the other is about 100,000 times greater. The electrostatic potential energy in the smaller bodies is enormously greater than that in the larger ones; if one of these small bodies were to explode and expand to the size of the larger ones, we should have a liberation of energy large enough to endow an α particle with the energy it possesses. Is it possible that the positive units of electricity were, to begin with, quite as small as the negative, but while in the course of ages most of these have passed from the smaller stage to the larger, there are some small ones still lingering in radio-active substances, and it is the explosion of these which liberates the energy set free during radio-active transformation?

The properties of radium have consequences of enormous importance to the geologist as well as to the physicist or chemist. In fact, the discovery of these properties has entirely altered the aspect of one of the most interesting geological problems, that of the age of the earth. Before the discovery of radium it was supposed that the supplies of heat furnished by chemical changes going on in the earth were quite insignificant, and that there was nothing to replace the heat which flows from the hot interior of the earth to the colder crust. Now when the earth first solidified it only possessed a certain amount of capital in the form of heat, and if it is continually spending this capital and not gaining any fresh heat it is evident that the process cannot have been going on for more than a certain number of years, otherwise the earth would be colder than it is. Lord Kelvin in this way estimated the age of the earth to be less than 100 million years. Though the quantity of radium in the earth is an exceedingly small fraction of the mass of the earth, only amounting, according to the determinations of Profs. Strutt and Joly, to about five grammes in a cube whose side is 100 miles, yet the amount of heat given out by this small quantity of radium is so great that it is more than enough to replace the heat which flows from the inside to the outside of the earth. This, as Rutherford has pointed out, entirely vitiates the previous method of determining the age of the earth. The fact is that the radium gives out so much heat that we do not quite know what to do with it, for if there was as much radium throughout the interior of the earth as there is in its crust, the temperature of the earth would increase much more rapidly than it does as we descend below the earth's surface. Prof. Strutt has shown that if radium behaves in the interior of the

earth as it does at the surface, rocks similar to those in the earth's crust cannot extend to a depth of more than forty-five miles below the surface.

It is remarkable that Prof. Milne from the study of earthquake phenomena had previously come to the conclusion that rocks similar to those at the earth's surface only descend a short distance below the surface; he estimates this distance at about thirty miles, and concludes that at a depth greater than this the earth is fairly homogeneous.

Though the discovery of radio-activity has taken away one method of calculating the age of the earth, it has supplied another.

The gas helium is given out by radio-active bodies, and since, except in beryls, it is not found in minerals which do not contain radio-active elements, it is probable that all the helium in these minerals has come from these elements. In the case of a mineral containing uranium, the parent of radium in radio-active equilibrium, with radium and its products, helium will be produced at a definite rate. Helium, however, unlike the radio-active elements, is permanent and accumulates in the mineral; hence if we measure the amount of helium in a sample of rock and the amount produced by the sample in one year, we can find the length of time the helium has been accumulating, and hence the age of the rock. This method, which is due to Prof. Strutt, may lead to determinations not merely of the average age of the crust of the earth, but of the ages of particular rocks and the date at which the various strata were deposited; he has, for example, shown in this way that a specimen of the mineral thorianite must be more than 240 million years old.

The physiological and medical properties of the rays emitted by radium is a field of research in which enough has already been done to justify the hope that it may lead to considerable alleviation of human suffering. It seems quite definitely established that for some diseases, notably rodent ulcer, treatment with these rays has produced remarkable cures; it is imperative, lest we should be passing over a means of saving life and health, that the subject should be investigated in a much more systematic and extensive manner than there has yet been either time or material for. Radium is, however, so costly that few hospitals could afford to undertake pioneering work of this kind; fortunately, however, through the generosity of Sir Ernest Cassel and Lord Iveagh a Radium Institute, under the patronage of his Majesty the King, has been founded in London for the study of the medical properties of radium, and for the treatment of patients suffering from diseases for which radium is beneficial.

The new discoveries made in physics in the last few years, and the ideas and potentialities suggested by them, have had an effect upon the workers in that subject akin to that produced in literature by the Renaissance. Enthusiasm has been quickened, and there is a hopeful, youthful, perhaps exuberant, spirit abroad which leads men to make with confidence experiments which would have been thought fantastic twenty years ago. It has quite dispelled the pessimistic feeling, not uncommon at that time, that all the interesting things had been discovered, and all that was left was to alter a decimal or two in some physical constant. There never was any justification for this feeling, there never were any signs of an approach to finality in science. The sum of knowledge is at present, at any rate, a diverging, not a converging series. As we conquer peak after peak we see in front of us regions full of interest and beauty, but we do not see our goal, we do not see the horizon; in the distance tower still higher peaks, which will yield to those who ascend them still wider prospects, and deepen the feeling, whose truth is emphasized by every advance in science, that "Great are the works of the Lord."

METHODS OF DRYING SOAP.

It is impossible to remove rapidly by intense heating the greater part of the water of freshly-made soap. This treatment would melt the soap, form a dry, hard crust which would prevent evaporation from the interior or, at least, cause more or less serious deformation. In the oldest method of drying soap, the cakes or bars are placed on racks in large, moderately-heated and well-ventilated rooms. Two or three months are required for drying in this way. In a more rational and more rapid process, used in most large soap factories, the soap is placed on racks on cars which are drawn through a drying gallery in a direction opposed to that of a current of air. By this device the drying is accelerated and much space is saved.

According to an article in an Italian technical journal, the best way to obtain a dry soap is to use as little water as possible in forming the paste. The comparatively dry fresh soap thus produced can be heated strongly and dried quickly without losing its shape. The simplest method to begin the desiccation is to cause the soap to move slowly down an inclined tunnel, having a double bottom heated by steam, against an ascending current of hot air. After the soap has been dried as well as possible by this process, the desiccation may be completed in the Barabino apparatus, primarily designed for the rapid cooling of soap. This apparatus consists of a series of double-walled iron chambers, communicating with each other, the temperature of which can easily be varied within wide limits. The apparatus is very useful for the rapid cooling of soap, especially in hot climates. For soaps which are not boiled, the entire process of manufacture, including saponification and desiccation, can be conducted in this apparatus, by properly regulating and varying the temperature. In like manner, soap which has already been partially dried can be desiccated to any desired degree, even to absolute dryness, and subsequently cooled, more or less rapidly, according to its composition.

ENGINEERING NOTES.

In Bardill's method of removing incrustations from lead furnaces, a dynamite cartridge, inclosed in a system of stoppered iron tubes, is pushed by a long iron rod through the efflux tube, into the bottom of the furnace, where it is packed with asbestos as a safeguard against premature explosion and against excessive violence at the moment of explosion. Between the introduction of the cartridge and its explosion elapses an interval of 15 to 25 seconds, during which the operator can seek a safe place. The shattered incrustations rise to the surface of the next charge of melted lead and can be skimmed off without difficulty.

A new and ingenious device for loading coal has been installed at Emden, Germany. The apparatus consists of two colossal traveling cranes, which move at right angles to the front of the wharf and the sides of the vessel. The outer section of the frame, which is ordinarily raised into a vertical position, may be lowered so as to extend horizontally over the vessel. In this way the coal is carried directly from the railway car to the hold of the ship by a vertical hoist, a horizontal traverse, and a vertical descent. The apparatus is operated electrically by means of a current of about 500 volts. The speeds attained are 4 feet per second for the upward hoist, 6 for the descent, and 10 or 12 for the horizontal traverse.

At Sheffield, England, was recently held an exhibition of devices for saving fuel and suppressing the smoke nuisance. Sir Oliver Lodge made an address in which he indicated methods of increasing the efficiency of the fuel and emphasized the advantage of utilizing the heat radiated by furnaces. For domestic use, he recommended gas, and expressed the wish that the gas should be generated at the coal mines and that no other fuel should be admitted into cities. A great variety of apparatus using gas as fuel was exhibited, including gas-heated hot water radiators, smelting furnaces, enameling and tempering ovens, etc. There were special exhibits of the smokeless fuels known as "coalite" and "coaloxid." Mr. Scott Anderson recommended the employment of gas generators in factories.

Zinc was used instead of mortar, in the construction of the stone arches of a bridge which was built last year near Lyons, France. There are two elliptical arches, of 82 feet span, surmounted by a superstructure of armored concrete. The zinc was melted and poured into the interstices between the stones. The substitution of zinc for mortar increased the cost of construction by $2,600, or about $2.40 per square foot of the horizontal area of the bridge. The employment of zinc in this bridge of short span was an experiment, based on a series of experiments which M. Tavernier had previously made, with the object of remedying a notable defect of masonry structure, the weakness caused by the introduction of mortar or cement. Tavernier succeeded in making metallic joints 5 feet in depth without causing fractures in the stones, provided that these were perfectly dry. This result was obtained even with zinc, the melting point of which is 800 deg. F. For lead or zinc joints of the proper thickness, about 1/8 inch, the cost is about 4 cents per square foot. These experiments were followed by comparative tests of the strength of masses composed of cubical stones measuring 2½ inches every way joined with zinc and with mortar, respectively. It was found that zinc joints do not diminish the strength of stone when this is about 14,000 pounds per square inch. On the contrary, the strength is increased by the joint, if the metal is allowed to protrude, as a burr, which holds the face of the stone and also prevents the entrance of water. When the strength of the stone is between 14,000 and 18,500 pounds per square inch, the zinc joint shows a strength about 15 per cent less. With stronger stones the diminution is still greater. For joining very hard stones, therefore, a metal less compressible than zinc would be required. Joints of pure cement give equally good results, if they are very thin—less than 1/25 inch. Joints of mortar are weakened by disintegration, which begins at the surface and gradually extends inward.

TRADE NOTES AND FORMULÆ.

Kustan Alloy for Machine Parts.—To 12.1 parts of melted copper, add, while stirring, 0.78 part of sal ammoniac. This mixture is allowed to become thoroughly fluid and to it is added 87.12 parts of molten tin, stir vigorously and keep the mixture for a quarter of an hour, in a fluid condition. It is then poured into the molds for use. Kustan is said to resemble tin in its properties and to be particularly adapted for use, where metal surfaces in rotary or reciprocatory gliding motion rub together.

Pickling artistic wrought-iron work is easiest effected by means of dilute sulphuric acid. According to the character of the iron used in the wrought work and the thickness of the oxide coating and according to whether the dipping is to be done quickly or slowly, use a mixture of 1 part sulphuric acid to 10 to 100 parts of water. The weaker the pickle is made the longer the objects must be left in the fluid. After the dipping, the articles must be thoroughly dried, which is best effected by placing them in dry sawdust. After removing them from this, the articles should be touched as little as possible with the fingers. The well-dried articles are then coated with a thin celluloid varnish and will then retain, for a long time, their finished surface.

Soldering Powder for English Cast Steel.—I. Heat 64 parts of borax, 20 parts sal ammoniac, 10 parts ferrocyanide of potassium, 5 parts of rosin as a powder, with a little alcohol added, stirring the while until the mass has become homogeneous. After cooling, it is pulverized. II. 61 parts of borax, 52 parts ferrocyanide of potassium, 17 parts sal ammoniac, and 5 parts of rosin. The borax and sal ammoniac are heated together until both salts have melted into the water of crystallization of the borax; the heating is continued until homogeneity is obtained. III. 300 parts of borax, 200 parts of ferrocyanide of potassium, and 1 part Berlin blue, are pulverized, boiled down in water and dried by heat. The cooled mass is pulverized and mixed with 100 parts of wrought-iron filings. IV. Equal parts of borax, sal ammoniac and white pitch, all pulverized, are mixed.

To prevent the formation of boiler scale, according to the German patented process of Abel, Jr., he adds to the feed water phenol, cresol, or xylenol, preferably the cresol mixture prepared in large quantities. According to Neeske's patent, chromic salts (chromates) are added to the feed water, 2¼ pounds (preferably of acid chromic alkali salts) will suffice, for a small boiler, for weeks. According to Karlowa, the feed water is deprived of its carbonic acid by leaving it in a heated reservoir for three to four days. To the extent to which the water is freed from its free carbonic acid, the carbonate of lime, held in solution by its agency, will be precipitated. By thus remaining in the preheater it will be freed from its contents of carbonic acid and carbonate of lime, and will undergo further purification, suspended foreign matter settling in the reservoir. If the water still contains sulphate of lime, it can be separated in the boiler, not as an incrustation, but in the form of mud, by the addition of chloride of barium.

Luminous Mass.—20 parts of caustic lime, such as can be obtained by burning a dense limestone, for instance the solid shell of the *Hypopus vulgaris* is intimately mixed with 6 parts of powdered stick sulphur and 2 parts of starch. This mixture is then moistened with a solution of half a part of subnitrate of bismuth and 100 parts of alcohol, with the addition of a little hydrochloric acid, so that a thorough distribution of the bismuth is effected. When the alcohol has evaporated on exposure to the air, the mixture is to be heated in a covered crucible for about 20 minutes at bright red heat in a wood charcoal fire or a Perot gas furnace. When completely cooled, remove the thin layer of gypsum that covers the surface, pulverize the molten mass and heat again, for a quarter of an hour, at the above temperature. If we work carefully the powder will cake but slightly on the second heating, and a moderate pressure will disintegrate it so that it is finely reduced. A second pulverization, which is detrimental to the luminosity, is to be avoided.

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